Appendix L.

Hydrocarbon spill modelling study (RPS 2017e)

ConocoPhillips Barossa Project

Hydrocarbon Spill Modelling

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TERMS AND ABBREVIATIONS

ADCP - Acoustic Doppler Current Profiler

AMSA – Australian Maritime Safety Authority

ANZECC – Australian and New Zealand Environment and Conservation Council

API – American Petroleum Institute gravity. A measure of how heavy or light petroleum liquid is compared to water

ARMCANZ – Agriculture and Resources Management Council of Australia and New Zealand

ASA – Applied Science Associates

ASTM – American Society for Testing and Materials

BMSL – Below mean sea level

Bonn Agreement Oil Appearance Code – An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.

CFSR – Climate Forecast System Reanalysis

CMR – Commonwealth Marine Reserve

Condensate – The part of the hydrocarbon stream which is in a vapour formation and condenses to a liquid when cooled. Generally, the condensates are composed of C5 to C8 and have an API gravity >40.

cP – centipoise

CTD – Conductivity, temperature and depth profiler

Decay – The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.

Dissolved aromatic hydrocarbons – dissolved aromatic hydrocarbons within the water column with alternating double and single bonds between carbon atoms forming rings, containing at least one 6-membered benzene ring.

Entrained hydrocarbons – Droplets or globules of oil that are physically mixed (but not dissolved) throughout the water column. Physical entrainment can occur either during pressurised release from a sub-surface location, or through the action of breaking waves (>12 knots).

Evaporation – The process whereby components of the hydrocarbon mixture are transferred from the sea surface to the atmosphere

GODAE – Global Ocean Data Assimilation Experiment

HFO – Heavy Fuel Oil

HYCOM – Hybrid Coordinate Ocean Model

HYDROMAP – Three-dimensional advanced ocean/coastal computational model

IFO-180 – Intermediate fuel oil used as a propulsion fuel for ships. Has a maximum viscosity of 180 Cst.

ITOPF –International Tanker Owners Pollution Federation

Isopycnal layers – Water column layers with corresponding water densities

KEF – Key ecological feature

LC_{50} – Median lethal dose. The dose required for mortality of 50% of a tested population after a specified test duration.

NASA – National Aeronautics and Space Administration

NCEP – National Centre for Environmental Prediction

NOAA – National Oceanic and Atmospheric Administration

Marine diesel oil (MDO) – is a blend of gas oil and heavy fuel oil utilised in maritime-based diesel-fuelled engine applications.

MSL – mean sea level

ppb – parts per billion

RMAE – relative mean absolute error

RMS % – root-mean square percentage

RMSE – root-mean square error

RPS APASA – RPS APASA Pty Ltd

SIMAP – Spill Impact Mapping Analysis Program

USCG – US Coast Guard

USEPA – US Environmental Protection Authority

1. Introduction

1.1 Project background

ConocoPhillips Australia Exploration Proprietary (Pty) Limited (Ltd.) (ConocoPhillips), as proponent on behalf of the current and future co-venturers, is proposing to develop natural gas resources in the Timor Sea into high quality products in a safe, reliable and environmentally responsible manner. The Barossa Area Development (herein referred to as the “project”) is located in Commonwealth waters within the Bonaparte Basin, offshore northern Australia, and is approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

The development concept of the gas resource includes a floating production storage and offloading (FPSO) facility and a gas export pipeline that are located in Commonwealth jurisdictional waters. The FPSO facility will be the central processing facility to stabilise, store and offload condensate, and to treat, condition and export gas. The extracted lean dry gas will be exported through a new gas export pipeline that will tie into the existing Bayu-Undan to Darwin gas export pipeline. The lean dry gas will then be liquefied for export at the existing ConocoPhillips operated Darwin Liquefied Natural Gas (LNG) facility at Wickham Point, NT.

The key objective of the modelling study was to provide an assessment of the probabilities of hydrocarbon contact (at defined concentrations) and quantification of the effects on both the surface waters and within the water column (i.e. entrained and dissolved aromatic hydrocarbons) at depth levels relevant to the environmental values and sensitivities (e.g. shoals/banks, offshore reefs and islands, Commonwealth marine reserves etc.).

The assessment considers a number of spill scenarios involving different sources, spill durations and hydrocarbon types. The scenarios modelled were identified by ConocoPhillips to represent maximum credible scenarios that may be associated with the project.

The six hydrocarbon spill scenarios modelled were:

- Scenario 1 – 10 m^3 instantaneous surface release of marine diesel oil (MDO) to represent a refuelling incident in the Barossa offshore development area;
- Scenario 2 – 2,975 m^3 surface release of MDO over 6 hours to represent a single fuel tank rupture in the Barossa offshore development area;
- Scenario 3 – 19,400 m^3 surface release of Barossa condensate over 6 hours to represent a loss of contents from a storage tank following a vessel collision in the Barossa offshore development area;
- Scenario 4 – 16,833 m^3 subsea release of Barossa condensate over 80 days (approximately 210 m^3/day) to represent a long term subsea well blowout in the Barossa offshore development area;
- Scenario 5 – 650 m^3 surface release of heavy fuel oil (HFO) over 6 hours to represent a vessel collision leading to loss of an export tanker fuel tank; and
- Scenario 6 – 500 m^3 surface release of intermediate fuel oil (IFO)-180 over 6 hours to represent a ship collision and rupture of a single fuel tank from a pipelay vessel along the proposed gas export pipeline corridor.

The modelling provides an understanding of a conservative ‘outer envelope’ of the potential area that may be affected in the unlikely event of a large-scale hydrocarbon release. The modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill. Therefore, the modelling results represent the maximum extent that the released hydrocarbon may influence.

The coordinates of the release locations are presented in Table 1 and graphically in Figure 1. For Scenario 6, a point along the gas export pipeline corridor that represents a notional location close to a shoreline (i.e. Bathurst Island) was selected as the release location.

The closest environmental values and sensitivities to the Barossa offshore development area (FPSO facility) are submerged shoals and banks, including Lynedoch Bank (70 km to the south-east), Evans Shoal (64 km to the south-west) and Tassie Shoal (74 km to the south-west). The nearest emergent receptors to the gas export pipeline corridor are Bathurst Island and Melville Island. The closest submerged receptors to the gas export pipeline corridor are Goodrich Bank, Marie Shoal (both directly adjacent to the pipeline corridor), Shepparton Shoal (within the pipeline corridor) as well as Moss Shoal (3 km to the west).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (December to the following February), (ii) the transitional periods (March and September to November) and (iii) winter (April to August). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been anonymously peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Table 1 Barossa offshore development area and gas export pipeline corridor hydrocarbon spill modelling release locations

Release location	Scenario	Latitude	Longitude	Water depth (mLAT)
Barossa offshore development area release location	1 to 5	9° 52' 35.77" S	130° 11' 8.36" E	~230
Gas export pipeline corridor release location	6	11° 46' 8.4" S	129° 55' 22.8 E	~67

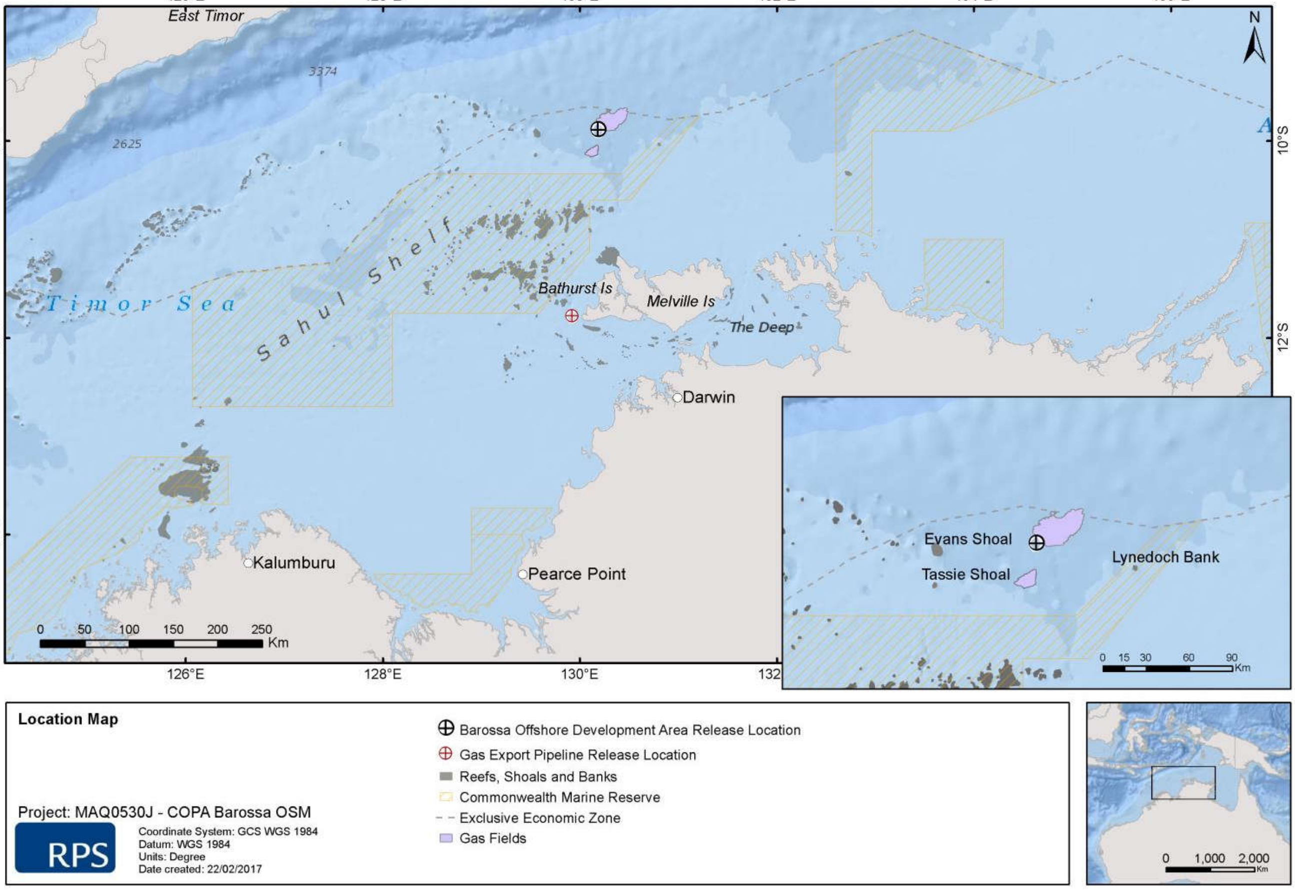


Figure 1 Map of the Barossa offshore development area and gas export pipeline hydrocarbon spill modelling release locations.

2. HYDROCARBON SPILL MODEL

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fates and effects of spilled hydrocarbons for either surface or subsea releases (Spaulding et al. 1994, French 1998, French, Schuttenberg and Isaji 1999, French-McCay 2003, French-McCay 2004).

The SIMAP model calculates two components: (i) the transport, spreading, entrainment, evaporation and decay of surface hydrocarbons and, (ii) the entrained and dissolved hydrocarbons released from the surface hydrocarbons into the water column. Input specifications for hydrocarbon-types include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

The SIMAP trajectory model separately calculates the movement of the material that is on the water surface or in the water column (as either entrained whole hydrocarbon droplets or dissolved hydrocarbons). The model calculates the transport of surface hydrocarbons from the combined forces exerted by surface currents and wind acting on the hydrocarbon. Transport of entrained and dissolved hydrocarbons (that is below the water surface) is calculated using the currents only.

The current and wind data input into the SIMAP model are discussed in Sections 2.1 and 2.2, respectively.

2.1 Development of regional current data

The project is located within the influence of the Indonesian Throughflow, a large scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. This results in sporadic deep ocean events causing surface currents to exceed 1.5 m/s (approximately 3 knots).

While the ocean currents generally flow toward the southwest, year-round, the internal gyres generate local currents in any direction. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time.

Whereas, the tidal currents are generally weaker in the deeper waters, with the influence of the tidal currents greatest surrounding regional reefs and islands. Therefore, it was critical to include the influence of both types of currents (ocean and tides) to rigorously understand the likely discharge characteristics in the project's area of influence.

A detailed description of the current (tidal and ocean) and wind data inputted into the model is provided below.

2.1.1 Tidal currents

The tidal circulation was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 26 years (Isaji and Spaulding 1984; Isaji et al. 2001; Zigic et al. 2003). In addition, HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) condensate spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by the Australian Maritime Safety Authority (AMSA).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984), Isaji et al. (2001) and Owen (1980).

2.1.1.1 Tidal grid setup

The HYDROMAP tidal grid was established over a domain that extended approximately 2,400 km (east–west) by 1,575 km (north–south) (Figure 2). Computational cells were square, with sizes varying from 8 km in the open waters down to 1 km in some areas, to more accurately resolve flows along the coastline, around islands and reefs, and over more complex bathymetry (Figure 3).

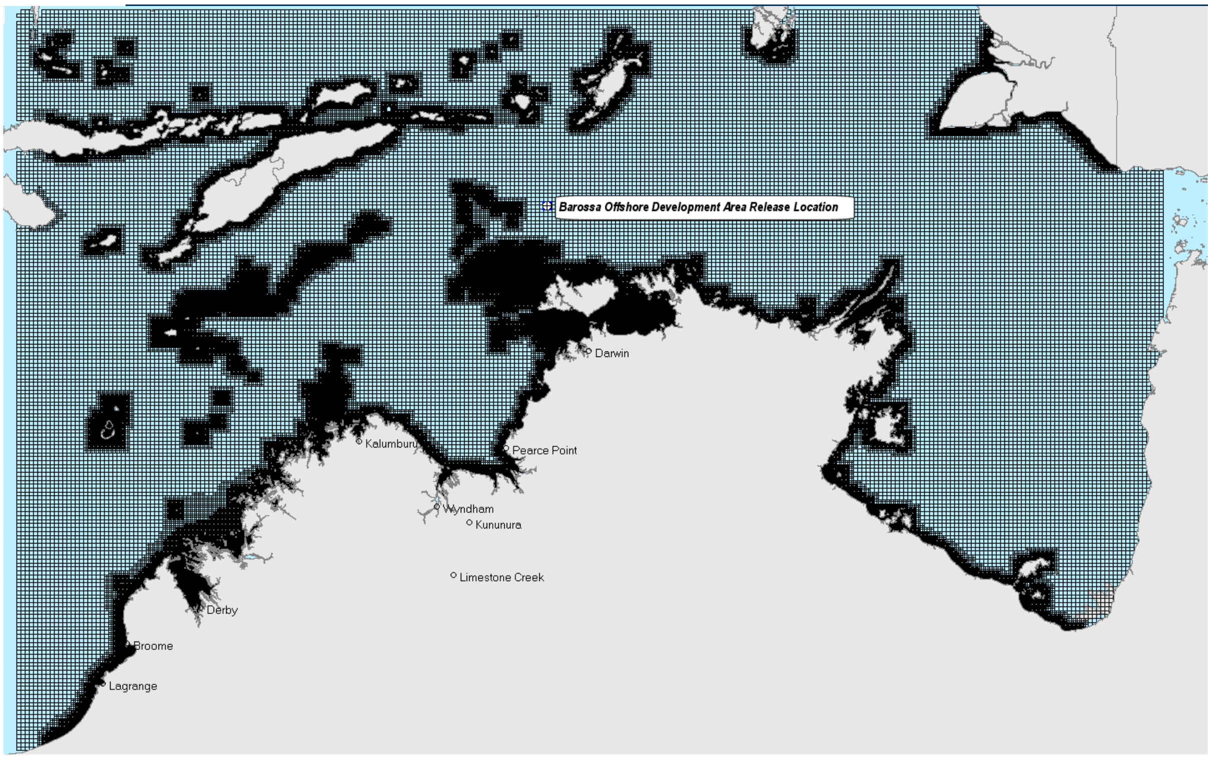


Figure 2 Map showing the extent of the tidal model grid. Note, darker regions indicate higher resolution.

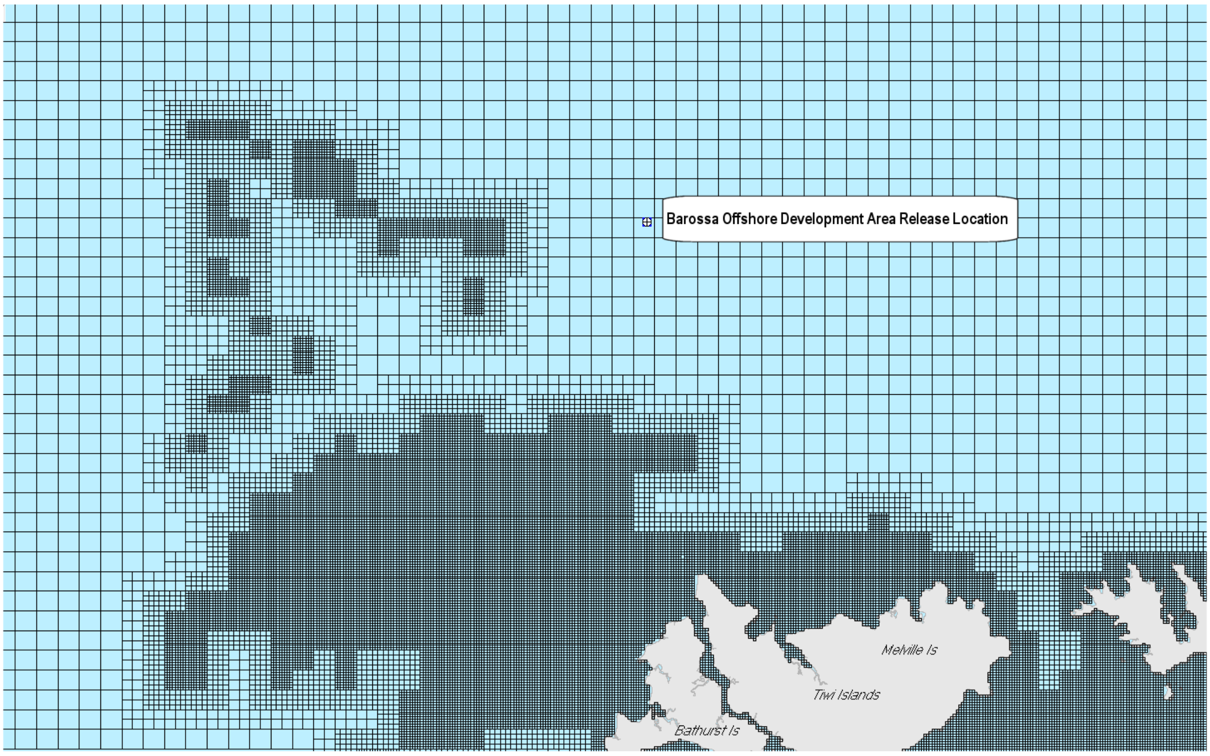


Figure 3 Zoomed in map showing the tidal model grid), illustrating the resolution sub-gridding in complex areas (e.g. islands, banks, shoals or reefs).

Bathymetry used in the model was obtained from multiple sources (Figure 4). This included bathymetry data sourced from the Geoscience Australia database and commercially available digitised navigation charts.

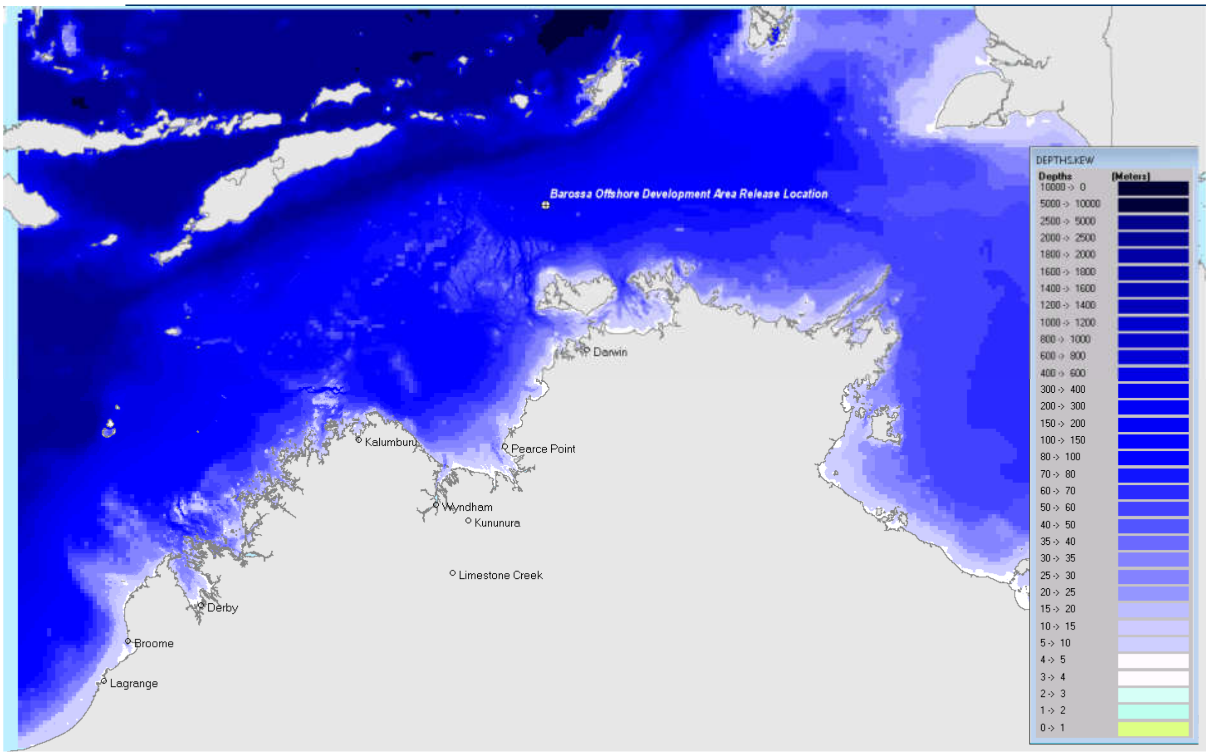


Figure 4 Map showing the bathymetry of the tidal model grid

2.1.2 Tidal conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The Topex-Poseidon satellite data is produced and quality controlled by the National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters that are capable of taking sea level measurements to an accuracy of less than 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005; see Fu et al., 1994; NASA/Jet Propulsion Laboratory 2013a; 2013b). In total these satellites carried out 62,000 orbits of the planet. The Topex-Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen 1995, Ludicone et al. 1998, Matsumoto et al. 2000, Kostianoy et al. 2003, Yaremchuk and Tangdong 2004, Qiu and Chen 2010). As such the Topex/Poseidon tidal data is considered accurate for this study.

2.1.3 Ocean currents

Data describing the flow of ocean currents was obtained from the Hybrid Coordinate Ocean Model (HYCOM) (see Chassignet et al. 2007, 2009), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast, assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al. 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of once per day. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this modelling study, the HYCOM hindcast currents were obtained for the years 2010 to 2014 (inclusive). Figure 5 shows example screenshots of the predicted HYCOM ocean currents during summer and winter conditions. The colours of the arrows indicate current speed (m/s).

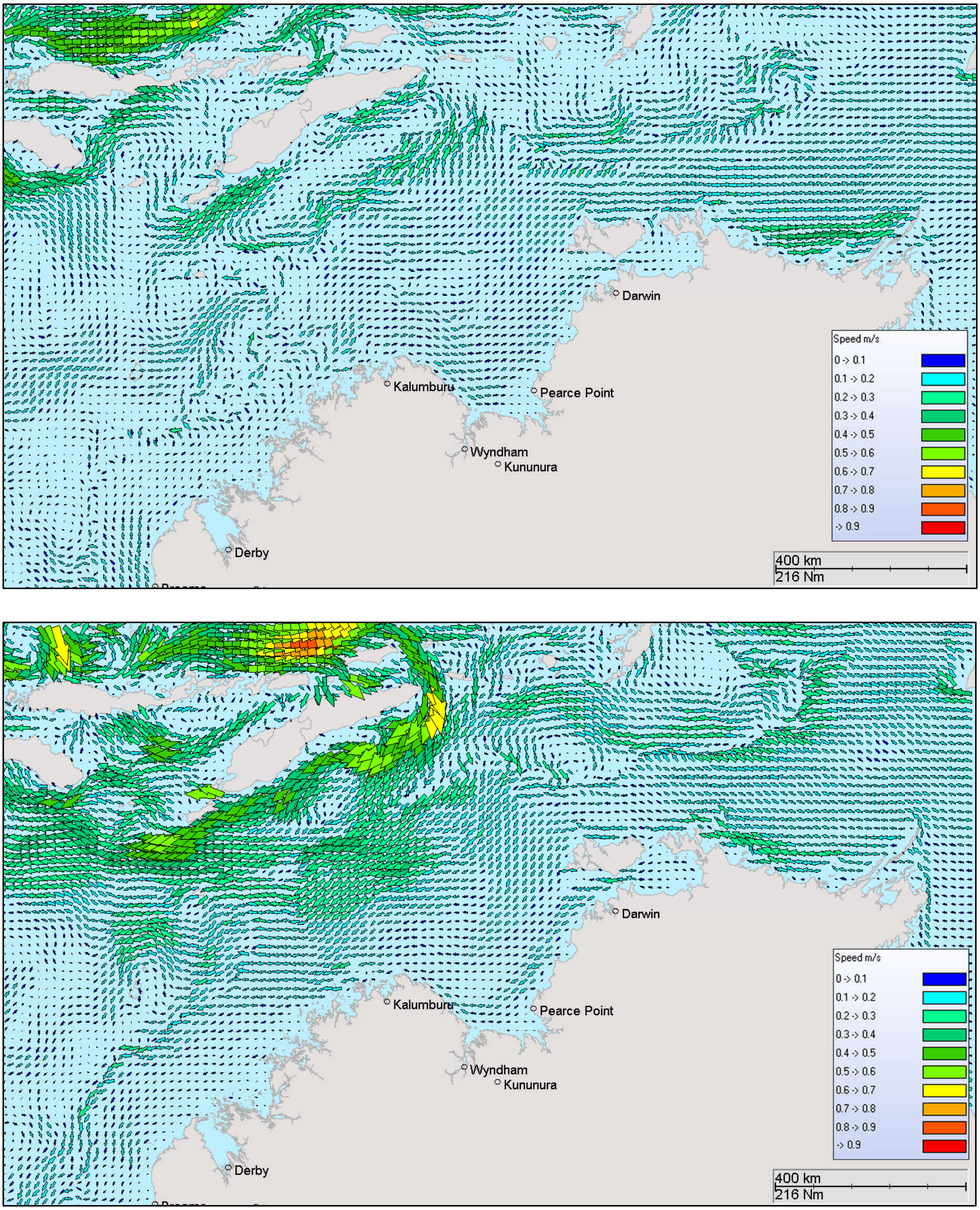


Figure 5 Modelled HYCOM surface ocean currents on the 6th February 2012, summer conditions (upper image) and 11th May 2012, winter conditions (lower image). Derived from the HYCOM ocean hindcast model (Note: for image clarity only every 2nd vector is displayed).

2.1.4 Surface currents in the Barossa offshore development area

Table 2 displays the average and maximum current speeds adjacent to the Barossa offshore development area release location. Data was derived by combining the HYCOM ocean data and HYDROMAP tidal data from 2010-2014 (inclusive). The average monthly current speeds in the Barossa offshore development area ranged between 0.11 m/s and 0.19 m/s. Under summer conditions the predominant current direction was toward the east and southwest. During winter months the currents were mostly to the west and southwest. Similarly, the currents during the transitional months generally flowed southwest. Seasonal average current speeds ranged between 0.12 m/s (summer), 0.13 m/s (winter) and 0.15 m/s (transitional).

Figure 6 and Figure 7 show monthly and seasonal surface current roses adjacent to the Barossa offshore development area release location. Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. The rose branches are each divided into segments of different colour according to speed intervals of 0.1 m/s, which represent current speeds within the monthly or seasonal datasets, respectively. The length of each coloured segment (indicative of speeds) is relative to the proportion of time the currents flow to the corresponding direction.

Table 2 Predicted average and maximum surface current speeds adjacent to the Barossa offshore development area release location. Data derived by combining the HYCOM ocean data and HYDROMAP tidal data from 2010-2014 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.13	0.43	East
	February	0.11	0.32	East
Transitional	March	0.11	0.28	East (variable)
Winter	April	0.12	0.30	West-northwest
	May	0.14	0.47	West and northward
	June	0.13	0.33	West (variable)
	July	0.12	0.40	Southwest (variable)
	August	0.13	0.38	Southwest
Transitional	September	0.14	0.40	Southwest
	October	0.17	0.32	Southwest
	November	0.19	0.36	Southwest
Summer	December	0.11	0.33	Southwest
	Minimum	**0.11**	**0.28**	
	Maximum	**0.19**	**0.47**	

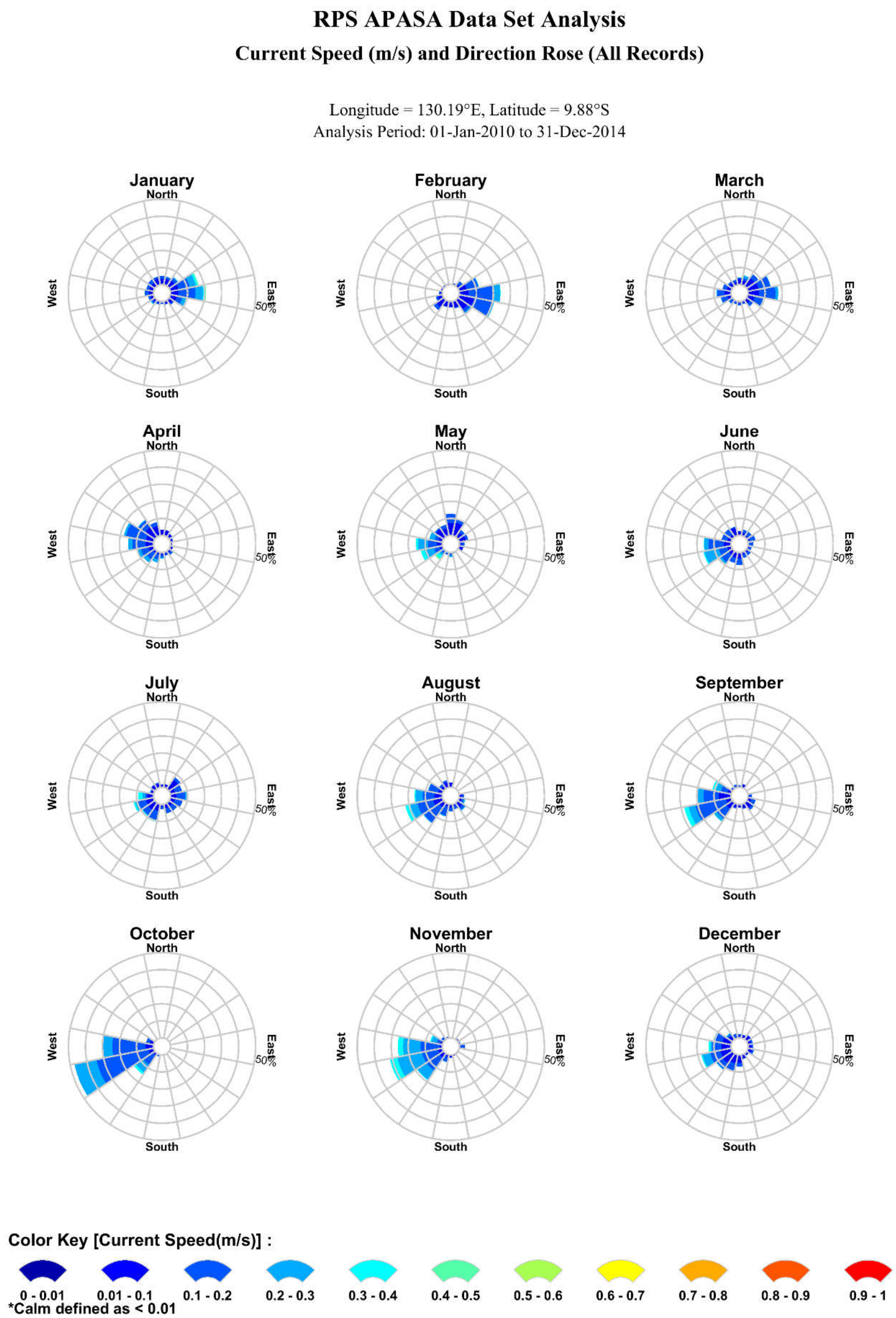


Figure 6 Predicted monthly surface current rose plots adjacent to the Barossa offshore development area release location. Data was derived by combining the HYCOM ocean currents and HYDROMAP tidal currents for 2010–2014 inclusive. The colour key shows the current speed (m/s), the compass direction provides the current direction (flowing towards), and the length of the rose branch indicates the proportion of time the currents flow for particular speed and direction combinations.

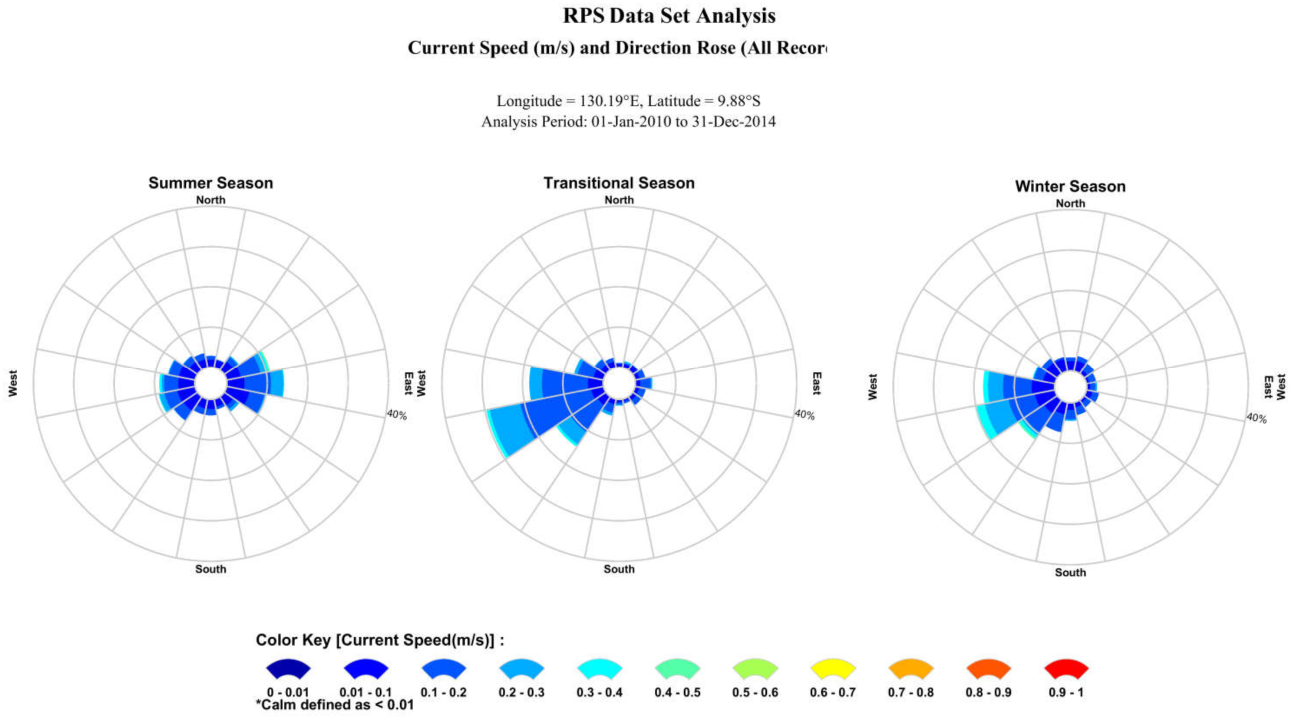


Figure 7 Seasonal surface current rose plots adjacent to the Barossa offshore development area release location. Data was derived by combining the HYCOM ocean currents and HYDROMAP tidal currents for 2010-2014 inclusive. The colour key shows the current speed (m/s), the compass direction provides the current direction (flowing towards), and the length of the rose branch indicates the proportion of time the currents flow for particular speed and direction combinations.

2.1.5 Tidal and current model validation

Fugro Survey Pty Ltd (Fugro) measured water levels and currents (speed and directions) at three locations within the Barossa offshore development area as part of the Barossa marine studies program (Figure 8; Fugro 2015). The measured data from the survey was made available to validate the predicted currents, which corresponds to the three identified seasons of the region (i.e. summer (December to February), transitional (March and September to November) and winter (April to August)).

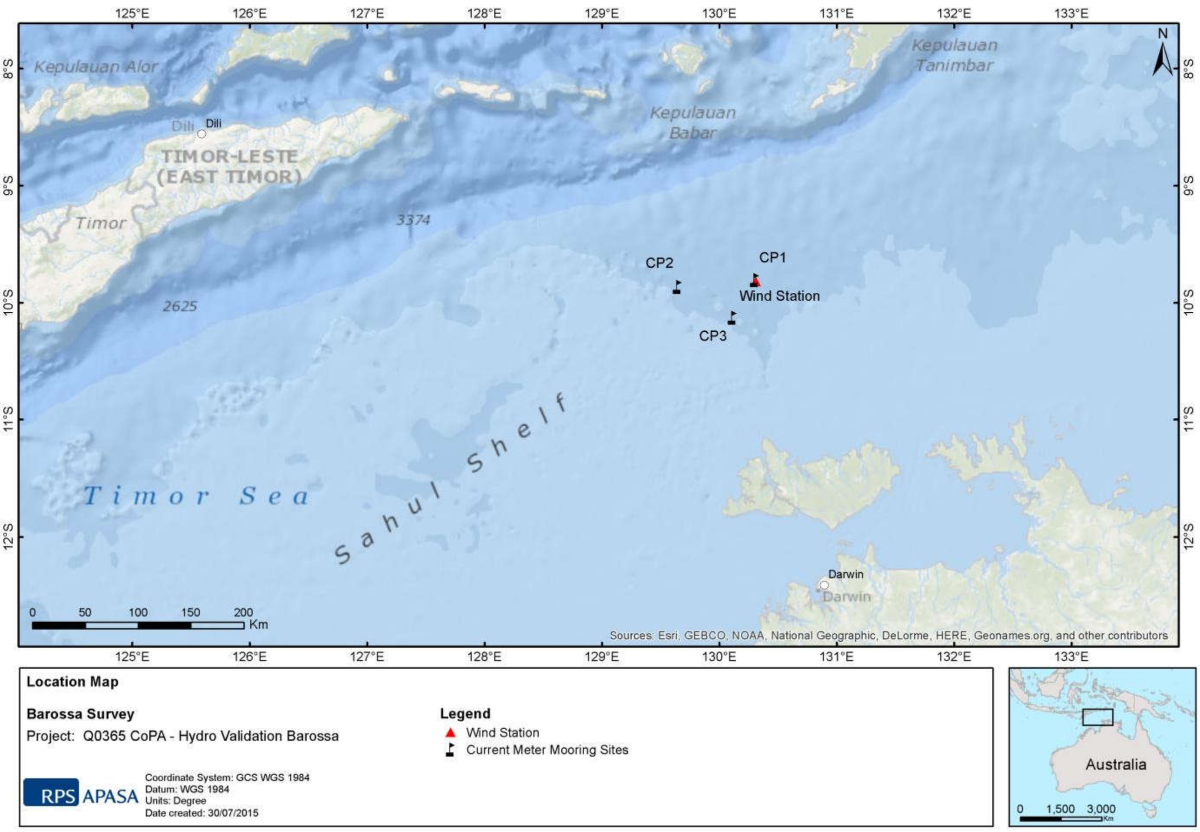


Figure 8 Locations of the CP1, CP2 and CP3 current meter moorings and the wind station

As an example, Figure 9 shows a comparison between the measured and predicted water levels at CP1 from 28 October 2014 to 14 March 2015. The figure shows a strong agreement in tidal amplitude and phasing throughout the entire deployment duration at the CP1 location.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001).

Table 3 shows the model performance when compared with measured water levels at CP1 from 28 October to 14 March 2015. According to the statistical measure, the HYDROMAP tidal model predictions were in very good agreement with the measured water levels at CP1.

Table 3 Statistical evaluation between measured water levels and HYDROMAP predicted water levels at CP1

Site	RMSE (m)	RMS (%)	RMAE	RMAE qualification
Mooring CP1	0.061	0.03	0.05	Very good

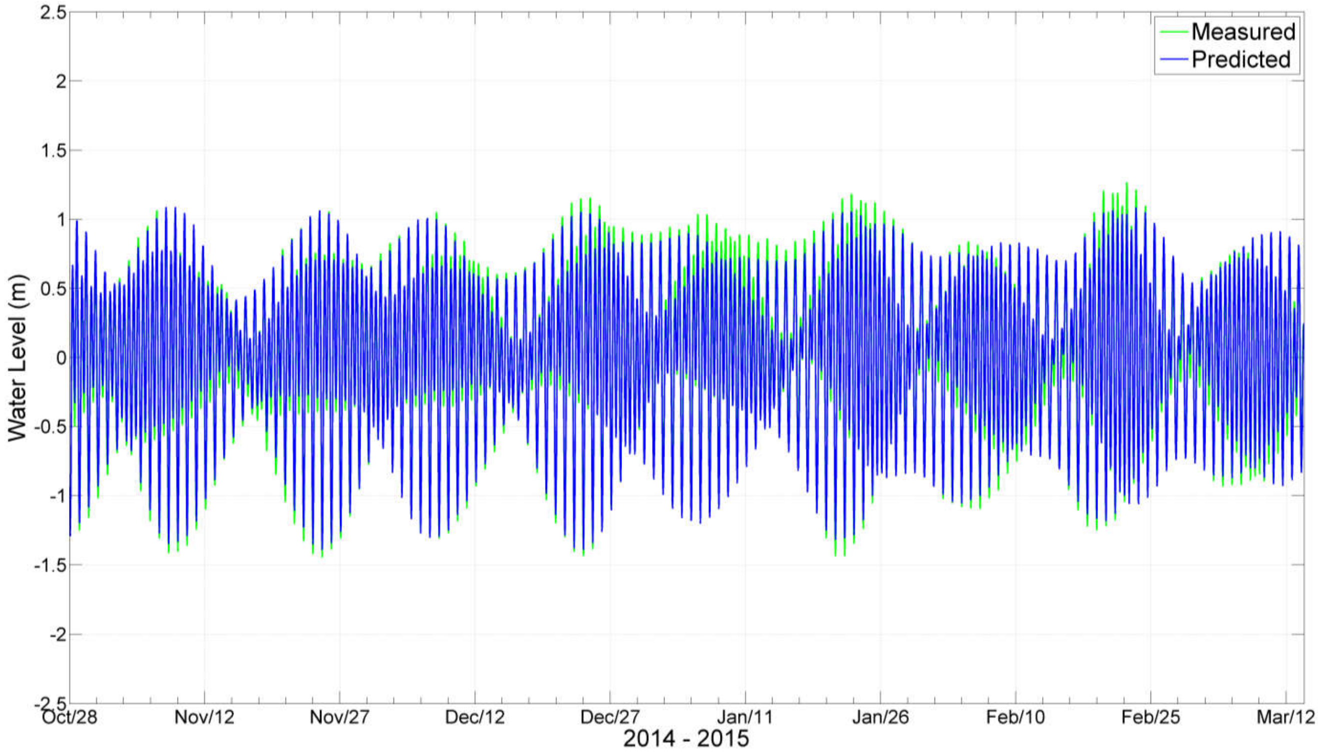


Figure 9 Comparison of measured and modelled water levels at CP1

In addition, the HYCOM ocean currents combined with HYDROMAP tidal currents were compared to the measured current speed and directions from the CP1, CP2 and CP3 moorings. Figure 10 to Figure 12 show current comparison plots of the measured and predicted currents at each location for a range of depths (10 m, 50 m and 125 m BMSL) to highlight the differences between the wind-influenced surface layers and the mid water column.

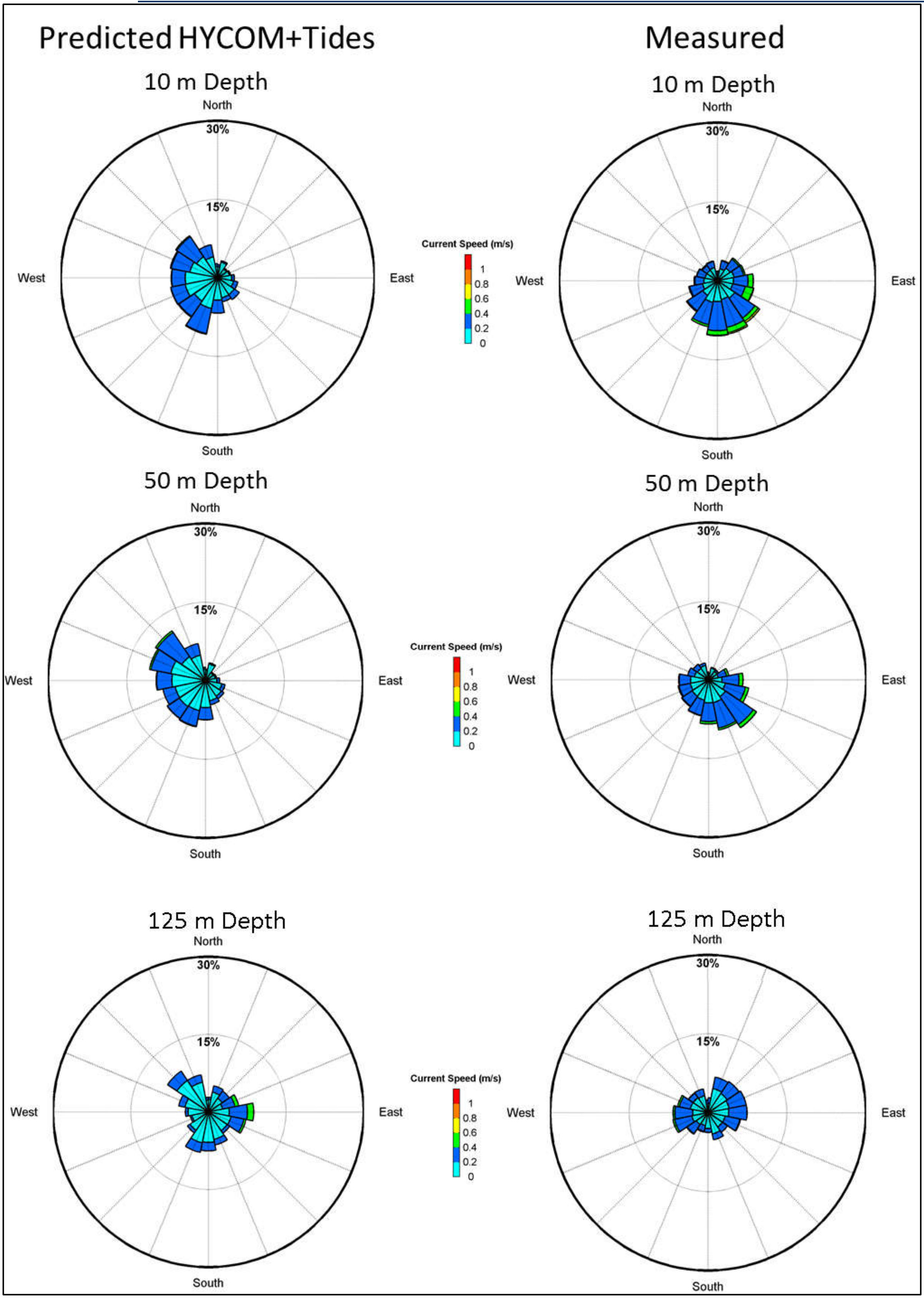


Figure 10 Comparison of predicted and measured current roses at CP1 from 9th July 2014 to 21st March 2015

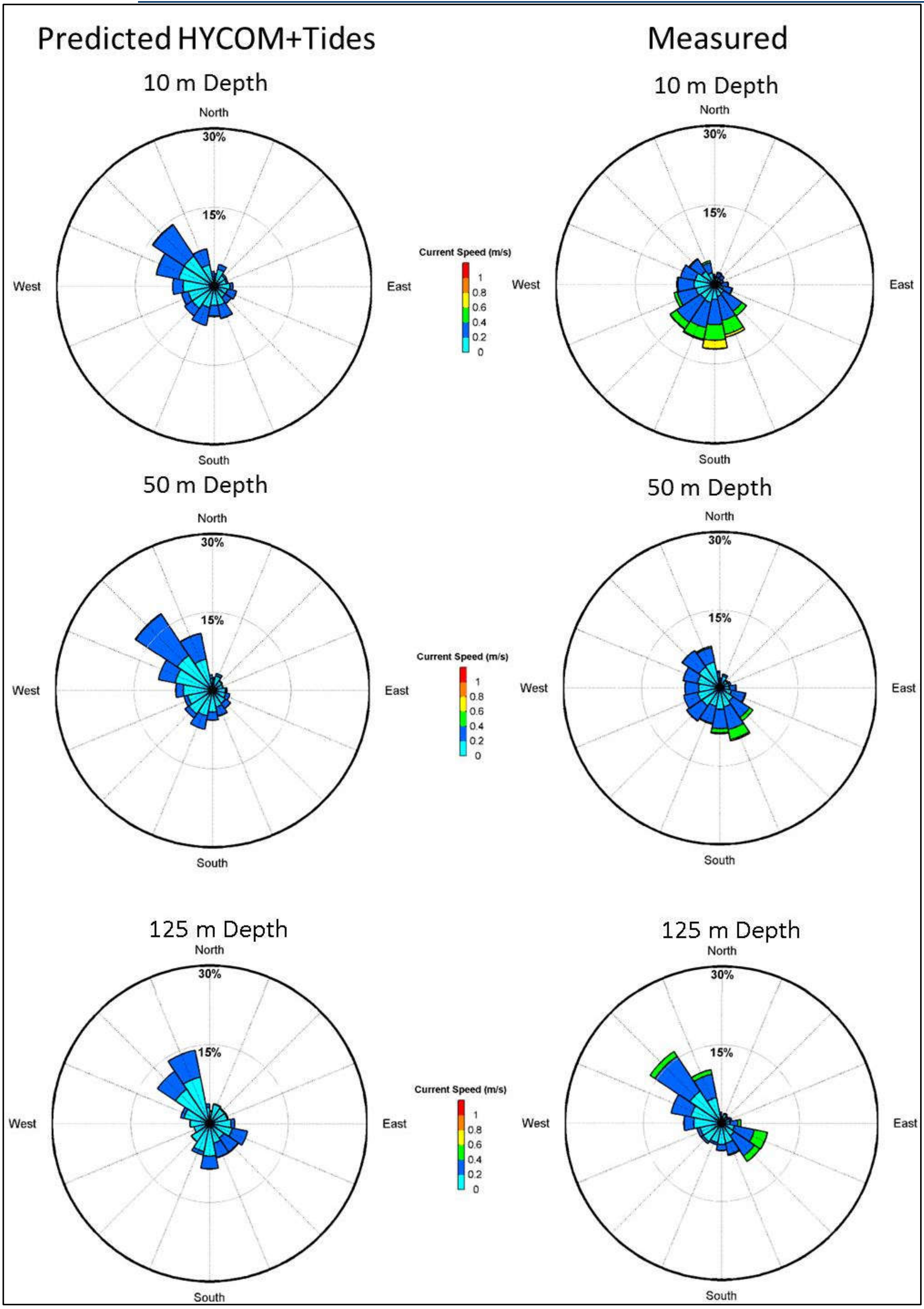


Figure 11 Comparison of predicted and measured current roses at CP2 from 10th July 2014 to 21st March 2015

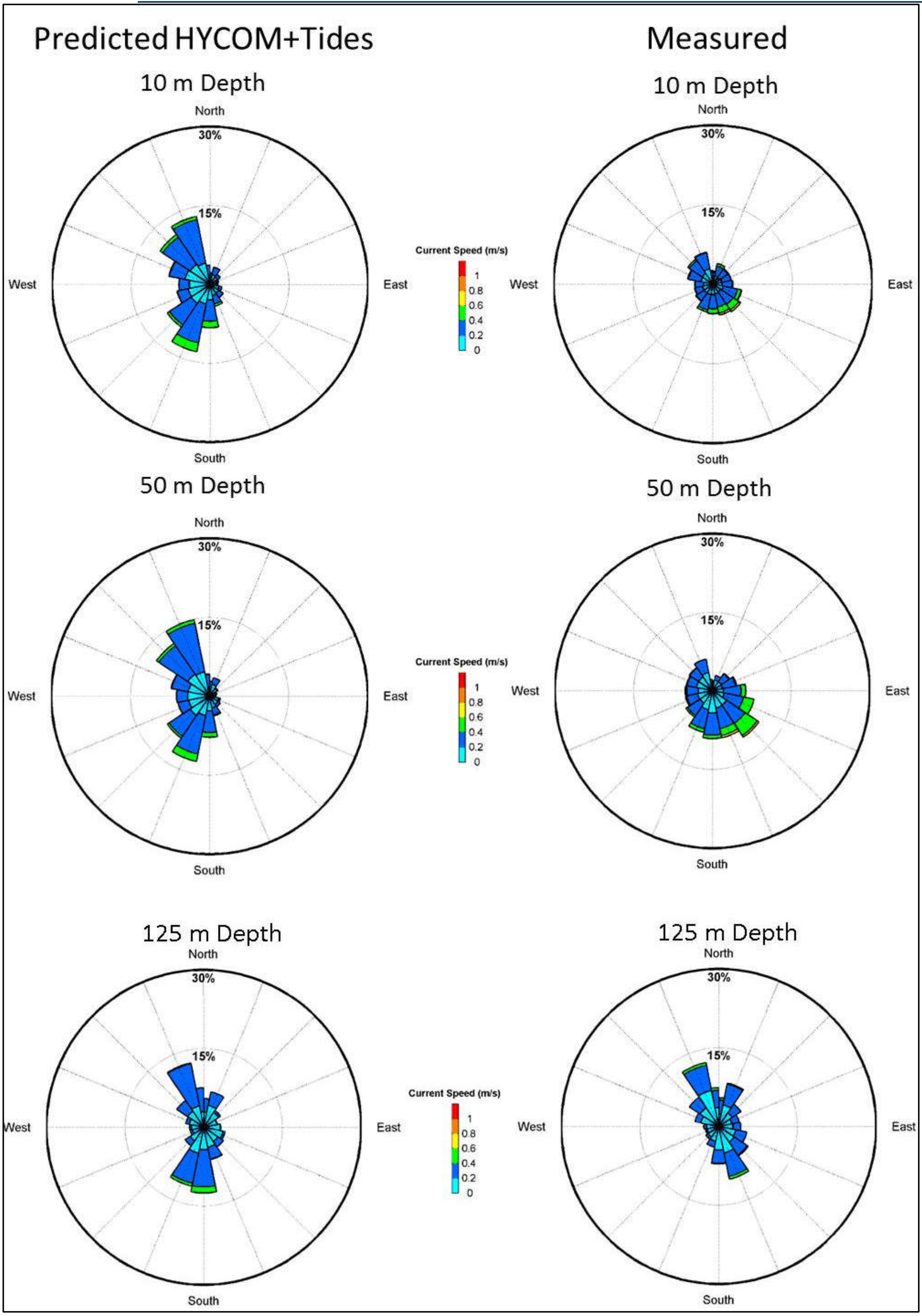


Figure 12 Comparison of predicted and measured current roses at CP3 from 9th July 2014 to 21st March 2015

Overall, there was a good agreement between the predicted and measured currents at each site and depth. The model predictions were also able to recreate the two-layer flow which can be seen in the measured data and the reduction in current speeds as function of depth. From 10 m down to approximately 100 m below mean sea level (BMSL) the currents generally flowed south-east, with little variation due to tidal changes. The model predictions replicated this behaviour. Below 100 m, the influence of the tides became more pronounced, rotating between a south-eastward flow and a north-westward flow with the turning of the tide. Both tidal-scale and large-scale fluctuations in currents were typically reproduced at a similar magnitude and timing.

There was some divergence between the predicted and measured currents, mostly between data from July to October inclusive, due to the occurrence of solitons (or high frequency internal waves that can produce unusually high currents) which was highlighted by Fugro (Fugro 2015). Despite these variations, the statistical comparisons between the measured and predicted current speeds indicate a reasonable to very good agreement (Table 4). Therefore, it can be concluded it is a good comparison and that the predicted current data reliably reproduced the complex conditions within the Barossa offshore development area and surrounding region. The RPS APASA (2015) model validation report provides a more detail regarding the tide and current comparison.

In summary, the Fugro (2015) data provides information specifically for the Barossa offshore development area and is considered the best available and most accurate data for this particular region. This data has been provided and reviewed by RPS APASA to confirm predicted currents applied are accurate. As a result, the current data used herein is considered best available and highly representative of the characteristics influencing the marine environment in the Barossa offshore development area.

Table 4 Statistical evaluation between averaged measured currents and HYCOM ocean current and HYDROMAP tidal current at CP1, CP2 and CP3 at varying water depths (July 2014 to March 2015)

Site	Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
Mooring CP1	10	0.14	0.71	20	Good
	50	0.14	0.63	22	Very good
	125	0.13	0.61	22	Very good
Mooring CP2	10	0.16	0.82	19	Reasonable
	50	0.14	0.81	17	Good
	125	0.16	0.72	22	Reasonable
Mooring CP3	10	0.15	0.88	18	Very good
	50	0.14	0.78	18	Very good
	125	0.13	0.60	21	Very good

2.2 Wind data

Wind data from 2010 to 2014 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) (Saha et al. 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. As shown in Figure 13 the wind nodes are spaced 33 km apart and contain datasets based on hourly intervals. Figure 13 also shows the location of the wind node used to generate a summary of the wind conditions nearby the Barossa offshore development area release location.

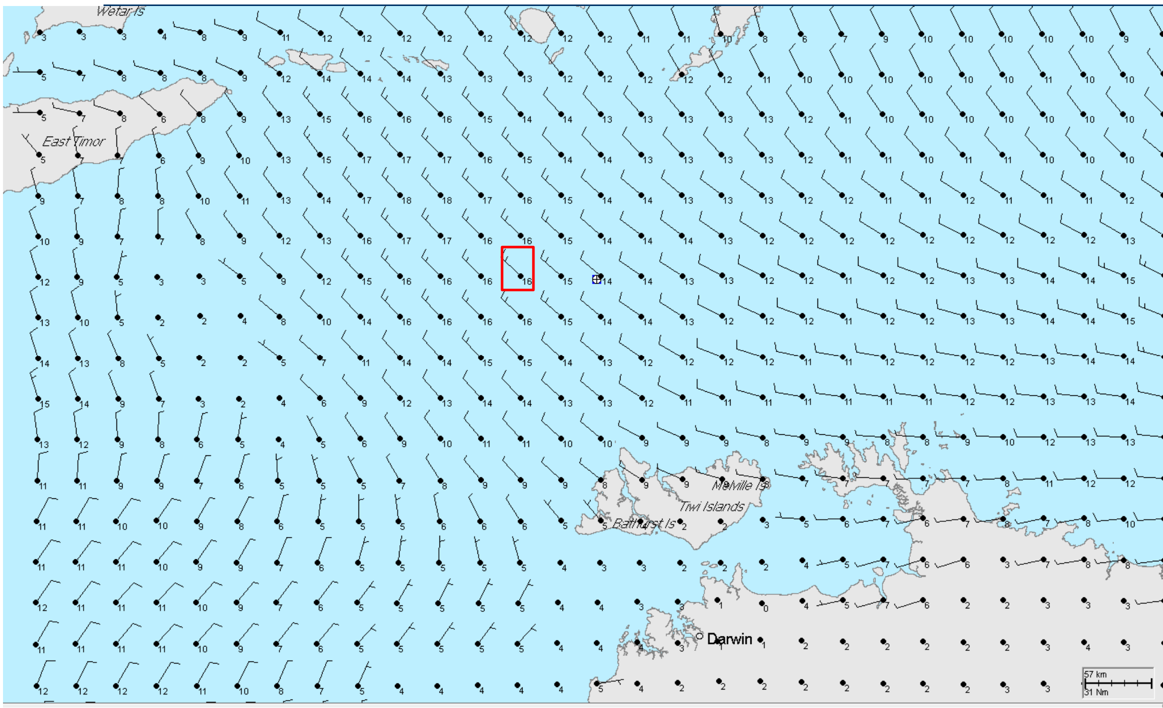


Figure 13 Image of the surrounding wind nodes used as input into the hydrocarbon spill model. Note the values describe the wind speed (knots) at that particular time-step. The red box indicates location of the wind node used to generate wind rose plots.

Table 5 displays the monthly average and maximum wind speeds and general directions derived from the CFSR wind node adjacent to the Barossa offshore development area release location. Figure 14 and Figure 15 show the corresponding monthly and seasonal wind rose plots.

The monthly average wind speeds ranged between 6.0 knots (November) and 15.9 knots (July) and were found to vary seasonally. During the summer season (December to February) winds were predominantly from the west with an average speed of 10.1 knots. During the winter season (April to August) winds were predominantly from the east-southeast with an average speed of 13.3 knots. The transitional period observed greater variations in wind direction and weaker wind speeds with an average of 8.0 knots.

Table 5 Predicted average and maximum winds for the closest station to the Barossa offshore development area

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	12.6	37.1	West
	February	10.7	31.1	West
Transitional	March	8.9	29.6	West-north-west (variable)
Winter	April	8.7	23.8	East-south-east
	May	13.7	25.1	East-south-east
	June	15.4	25.5	East-south-east
	July	15.9	25.9	East-south-east
	August	13.0	26.8	East-south-east
Transitional	September	9.4	23.9	East-south-east
	October	7.5	17.8	East-south-east
	November	6.0	21.4	East (variable)
Summer	December	7.0	26.5	West (variable)
	Minimum	**6.0**	**17.8**	
	Maximum	**15.9**	**37.1**	

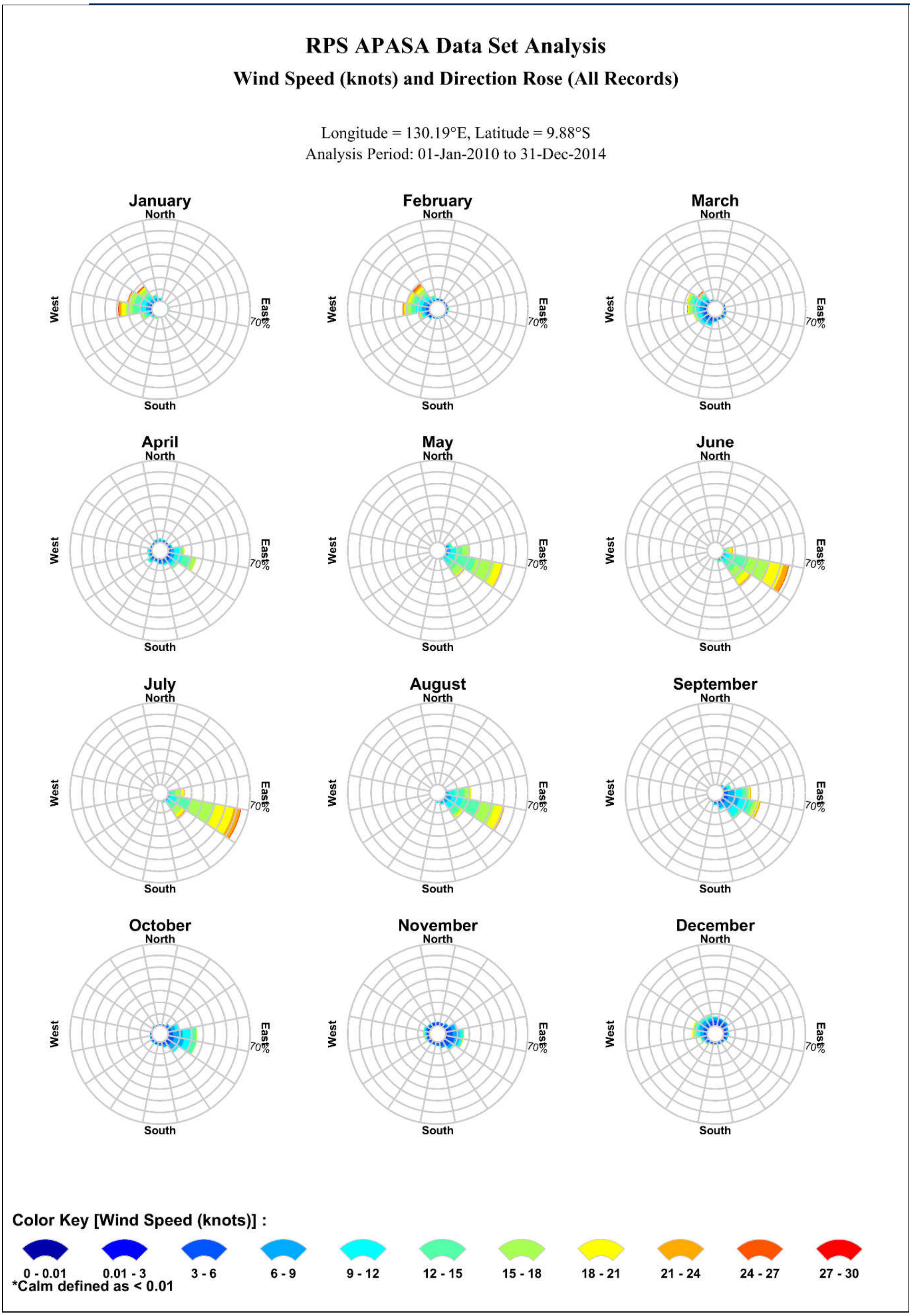


Figure 14 Monthly wind rose plots derived from CFSR data from 2010-2014 (inclusive), for an adjacent wind node to the Barossa offshore development area release location. The colour key shows the wind speed (knots), the compass direction provides the direction (from), and the length of the rose branch indicates the proportion of time the winds originate from for particular speed and direction combinations.

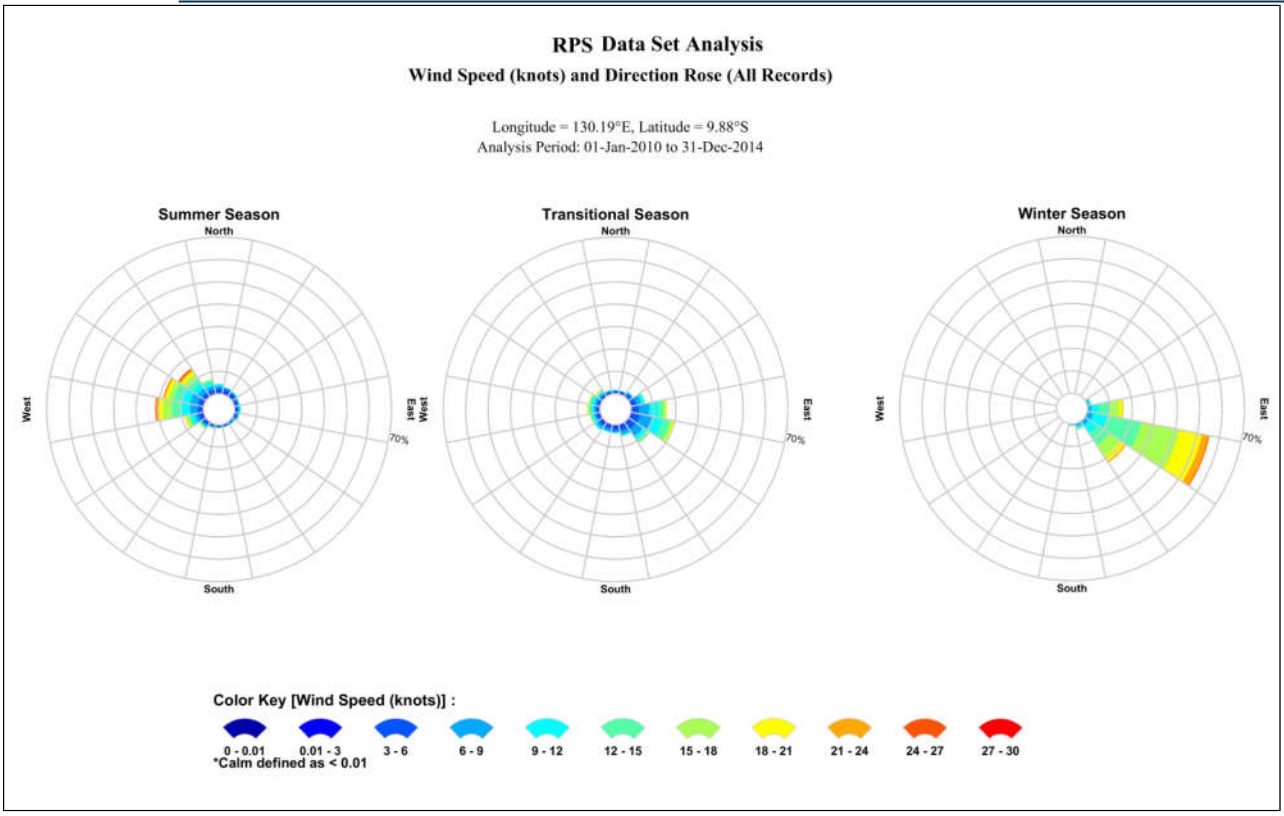


Figure 15 Seasonal wind rose plots derived from CFSR data from 2010-2014 (inclusive), for an adjacent wind node to the Barossa offshore development area release location. The colour key shows the wind speed (knots), the compass direction provides the direction (from), and the length of the rose branch indicates the proportion of time the winds originate from for particular speed and direction combinations.

2.2.1 Wind data validation

Fugro measured wind speed and direction, air temperature, air pressure and humidity (4 m above mean sea level (MSL)) as part of the Barossa marine studies program. As an example, Table 6 shows the measured average and maximum wind speeds between 8 July 2014 and 27 March 2015. During this period, winds were predominantly from the east, reaching a maximum speed of 29.9 knots in January (2015) and maximum average speed of 17.1 knots in January (2015).

Table 6 Measured average and maximum wind speeds in the Barossa offshore development area

Month	Average speed (knots)	Maximum speed (knots)
July 2014	15.4	24.7
August 2014	14.7	22.8
September 2014	9.0	16.6
October 2014	9.3	19.9
November 2014	7.6	19.8
December 2014	7.1	27.2
January 2015	17.1	29.9
February 2015	10.5	22.5
March 2015	10.8	19.6

As shown in Figure 16, there was a very good agreement between the measured and modelled winds of the general trends and although the model is not necessarily capturing the extremes, it does capture the shift in speed and direction over time. The good agreement is further confirmed in the rose plots shown in Figure 17 for the entire period.

Based on the qualitative assessment, the modelled data indicates a very good fit to the measured winds (Table 7). These statistics provide further confidence in the accuracy of the predicted wind data to be used for the spill and discharge modelling studies.

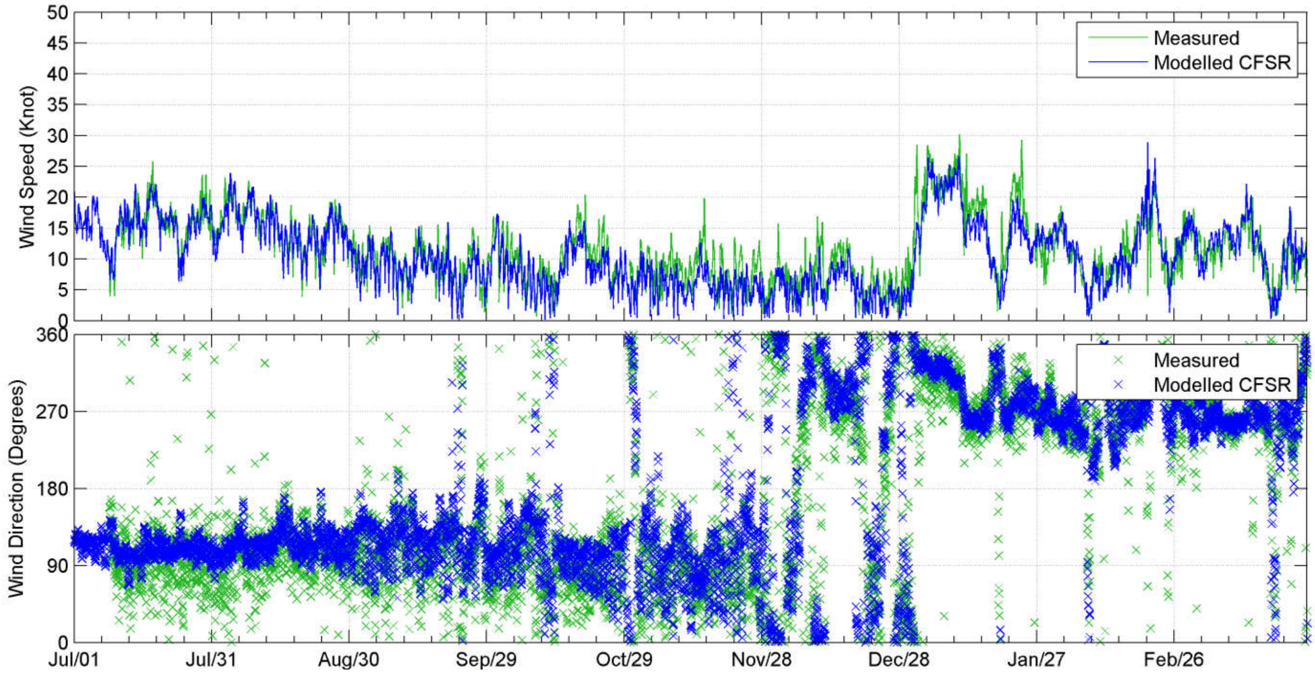


Figure 16 Comparison of the hourly measured and predicted wind speeds (upper image) and directions (lower image) (July 2014 to March 2015)

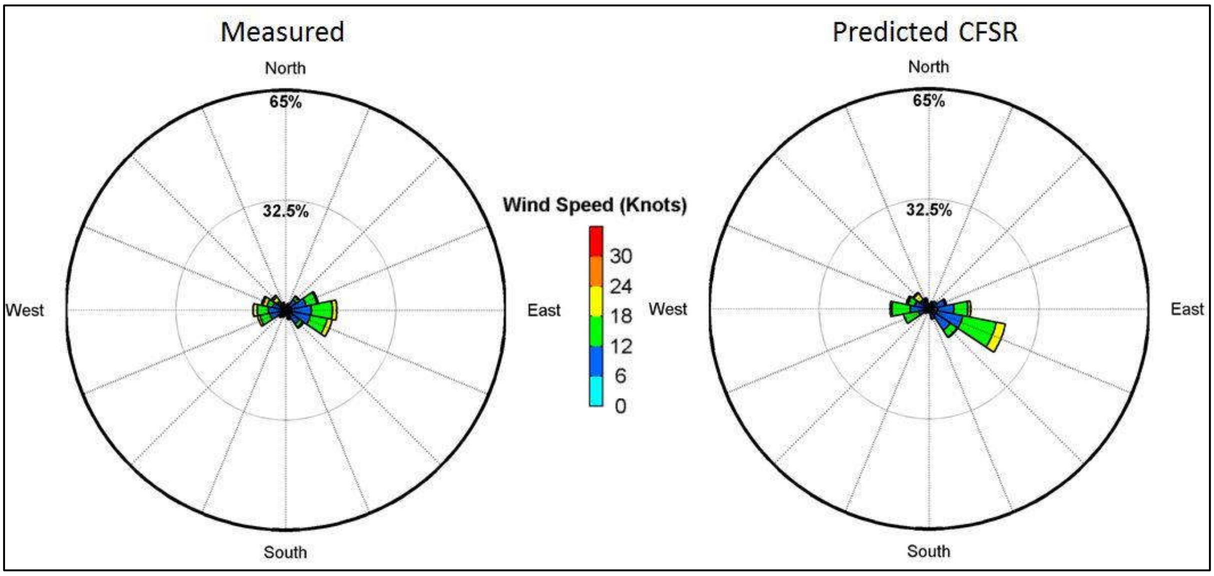


Figure 17 Combined comparison of wind rose plots between measured and predicted CFSR datasets for 8th July 2014 and 27th March 2015.

Table 7 Statistical evaluation between the measured and predicted winds

RMSE (knots)	RMS (%)	RMAE	RMAE qualification
2.8	10.5	<0.01	Very good

2.3 Drifter Buoy Deployment

Eighteen Pathfinder surface current drifter buoys were deployed on three separate field surveys (July 2014, January 2015 and April 2015) within the Barossa offshore development area to better understand the complex seasonal surface-water circulation. The July, January and April field surveys were selected to represent winter, summer and transitional conditions, respectively, within the study region. Figure 18 is a photograph of a deployed Pathfinder drifter buoy at sea and its dimensions.

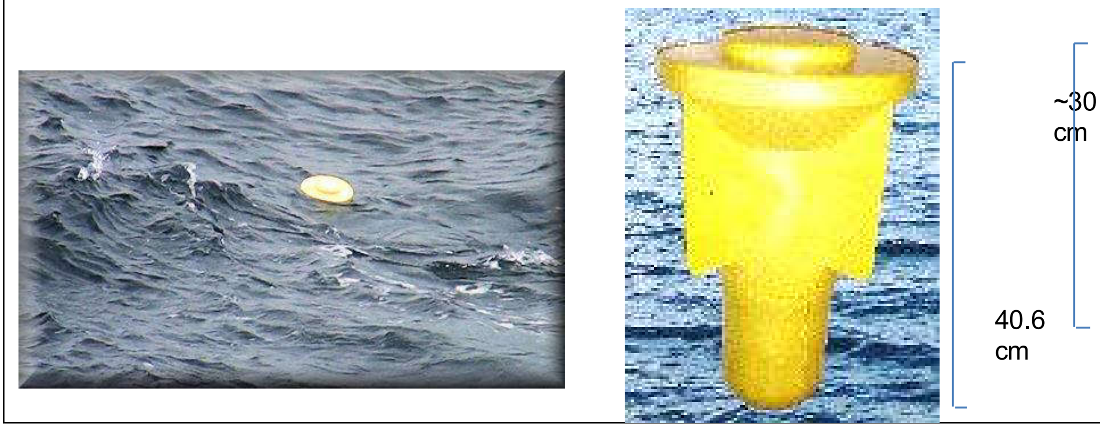


Figure 18 (left) Photograph of a deployed Pathfinder drifter buoy out at sea; and (right) the dimensions.

During the July 2014 field survey, the drifters provided positional updates for deployment periods ranging between 5–93 days. Whilst updates of the drifter positions during the January 2015 and April 2015 field surveys were provided during deployment periods ranging between 3–92 days and 6–51 days, respectively.

There was a clear distinction in directionality of the Pathfinder drifter buoys according to the seasonal metocean conditions. For example, all 12 drifters deployed under the winter conditions (July 2014) and transitional conditions (April 2015) drifted west from the release location. The six drifters deployed under summer metocean conditions (January 2015) drifted east from the release location.

2.3.1 Model comparisons and validation

Sixteen measured drifter tracks were selected from the field surveys to verify the ability of the hydrocarbon spill model to recreate their movements field surveys; five tracks during July - August (winter conditions), five tracks for January (summer conditions) and six during April (transitional conditions). The duration of the drifter tracks ranged from 6 days to 55 days and over distances between 32 km to 986 km. The measured drifter tracks were selected on the basis that they represented varying seasonal drift directions and starting positions, to principally show the accuracy of the model along sections of the track at any given time after the initial deployment. For the purposes of this report, only 6 of the drifter track comparisons are shown herein, two per season (see Table 8).

The modelled wind data and current data described in the sections above were used as input into the hydrocarbon spill software to recreate the modelled tracks. The model also included allowances for sub-grid scale turbulence and diffusion, specified as a horizontal diffusion coefficient value of 5 m^2/s.

Figure 19 to Figure 24 show the comparison plots of the six measured and predicted drifter tracks. Figure 19 and Figure 20 shows that the measured drifter tracks headed principally west under winter conditions (July to September 2014 deployments) and that the model predictions also drifted west. The drifter tracks during winter conditions were compared with the model predictions over durations ranging between 20 to 25 days and over vast distances ranging from 452 km to 636 km.

Figure 21 and Figure 22 shows that under summer conditions (January to March 2015 deployments) the measured drifters travelled either east or northeast from the comparison start point. The model also demonstrated the capability of accurately recreating the movement of the drifter buoys. The distances associated with the drifter track model comparisons ranged between 971 km and 986 km over 55 days.

During the transitional months (April to May 2015) the model was shown capable of correctly predicting the drifter movements which were mostly west (Figure 23 and Figure 24). However, on a number of occasions in the transitional months the drifters remained near the around the release location and in turn did not travel as far (31 km to 147 km) when compared to the winter and summer tracks.

Overall, the tracks demonstrated a good agreement between the measured and predicted drifts both in terms of distances and directions. Therefore, the results provide confidence in the hydrocarbon spill model to replicate spills in any direction based on the wind and current data used, even up to a travelled distance of 985 km.

Table 8 Drifter buoy identification number (ID), comparison duration and distance travelled buoy used as part of the drifter track model comparisons during winter, summer and transitional deployments.

Duration and distances used as part of the drifter track model comparisons								
Winter			Summer			Transitional		
Buoy ID	Duration (days)	Distance (km)	Buoy ID	Duration (days)	Distance (km)	Buoy ID	Duration (days)	Distance (km)
7579	25	452	7599	55	986	7578	20	32
7588	20	636	7601	55	971	7584	6	117

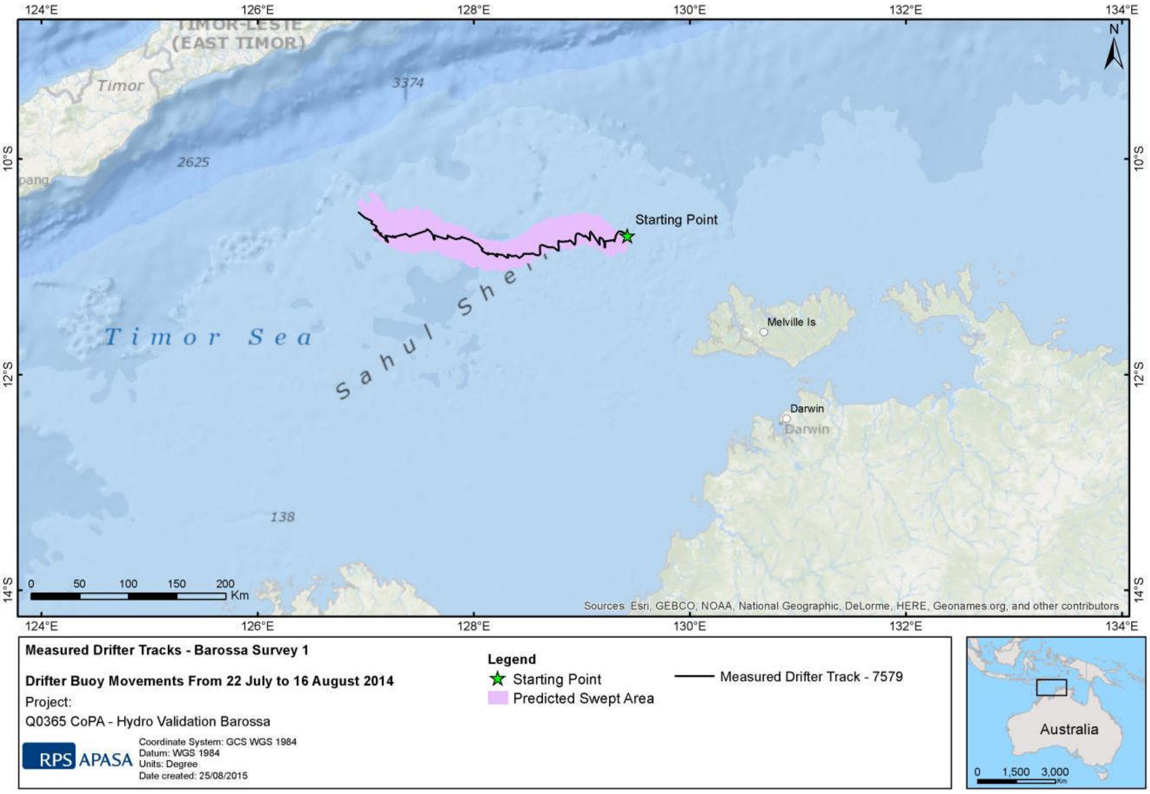


Figure 19 Comparison between the measured and predicted drifter track (buoy 7579) over a 25-day period between 22nd July and 16th August 2014 (winter conditions).

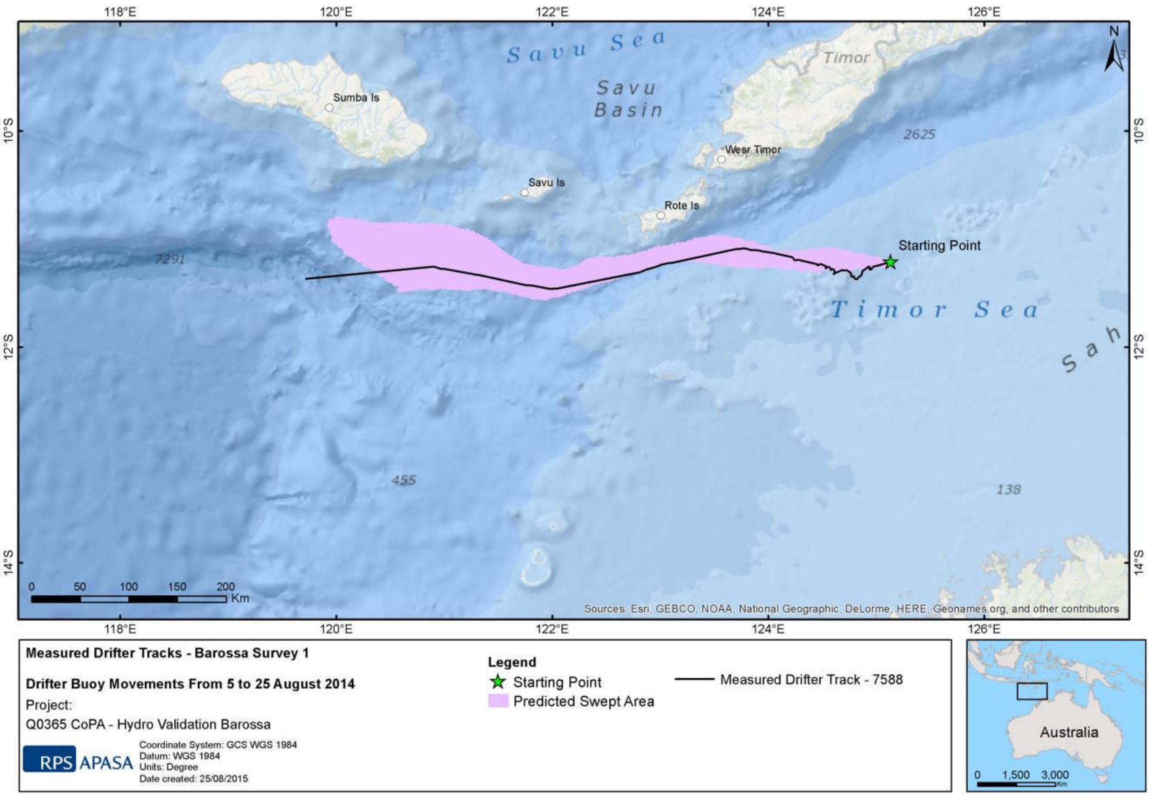


Figure 20 Comparison between the measured and predicted drifter track (buoy 7588) for a 20-day period in August 2014 (winter conditions)

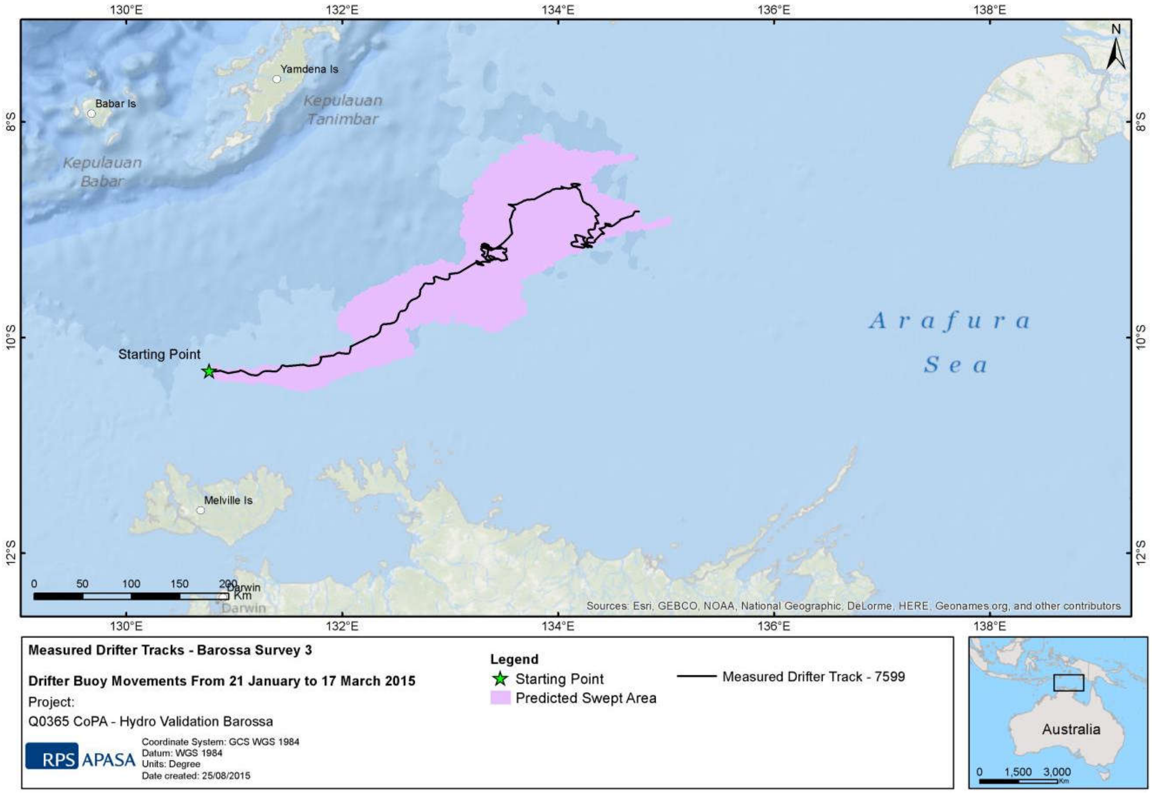


Figure 21 Comparison between the measured and predicted drifter track (buoy 7599) for a 55-day period between January and March 2015 (summer conditions)

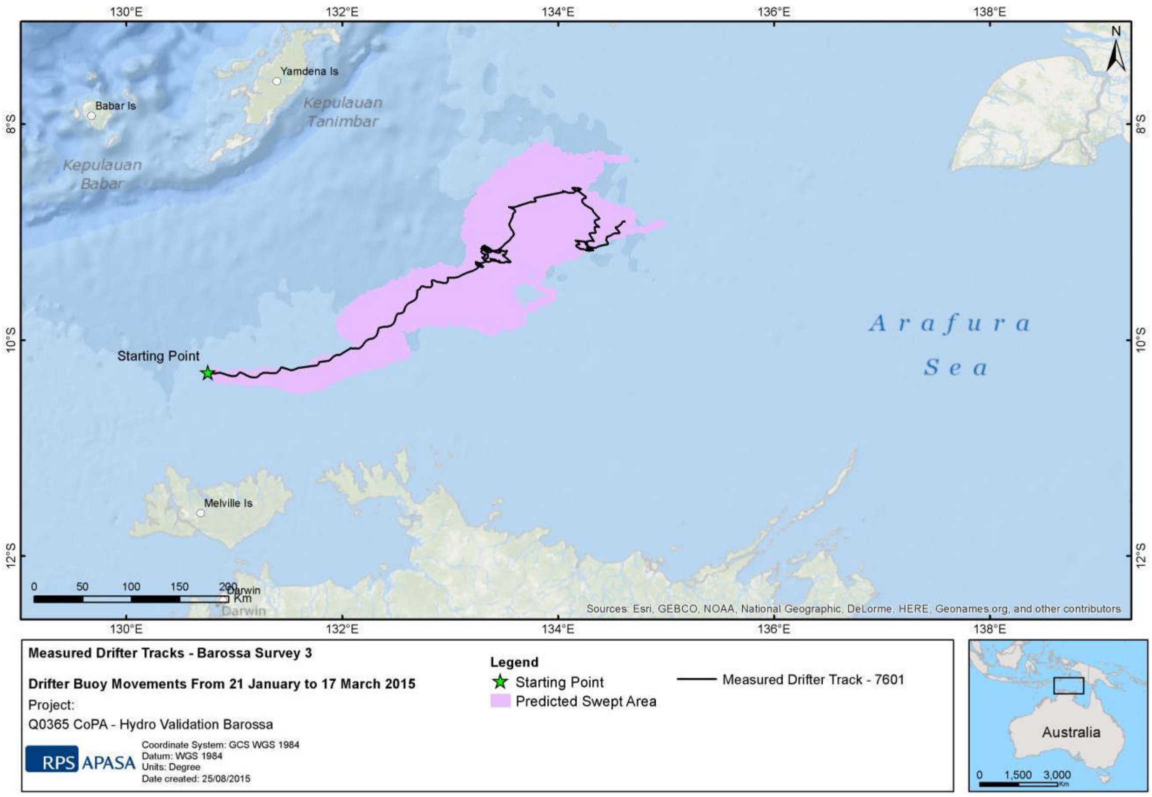


Figure 22 Comparison between the measured and predicted drifter track (buoy 7601) for a 55-day period between 21st January and 17th March 2015 (summer conditions)

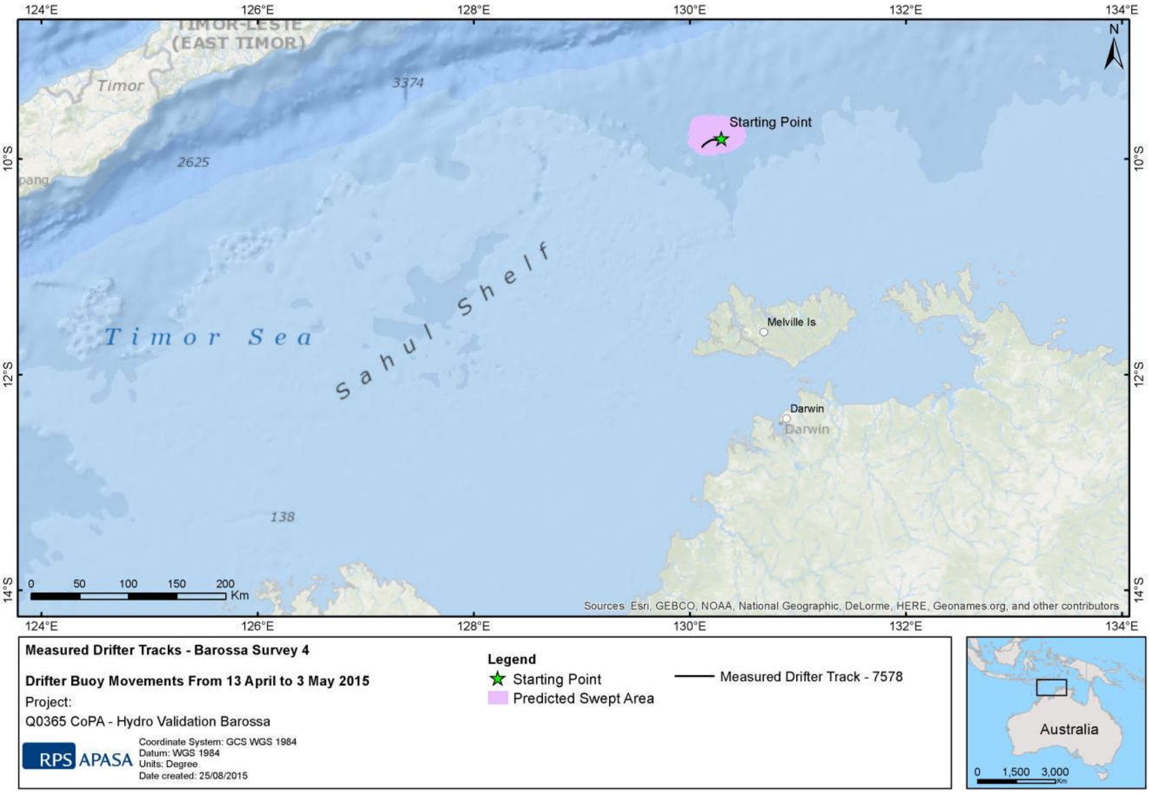


Figure 23 Comparison between the measured and predicted drifter track for a 20-day period between April and May 2015 (transitional conditions)

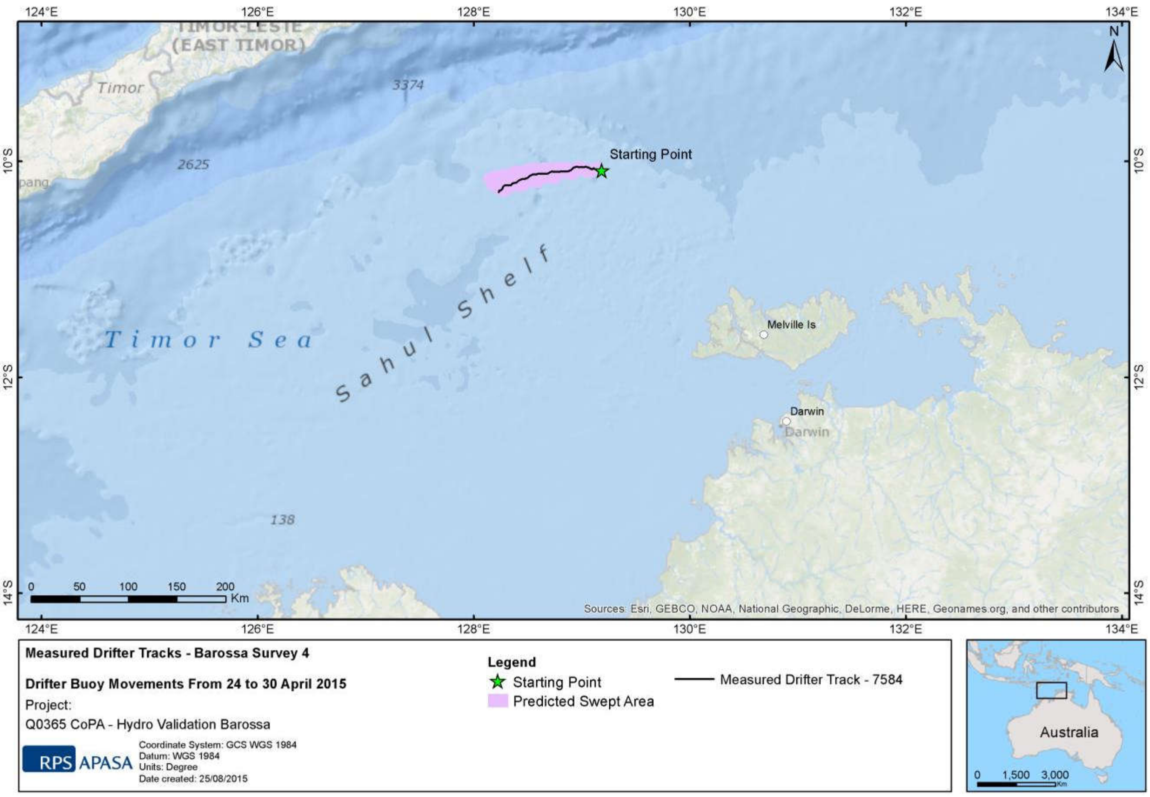


Figure 24 Comparison between the measured and predicted drifter track (buoy 7584) for a 6-day period between 24th April and 30th April 2015 (transitional conditions)

2.4 Ocean temperature and salinity

To accurately represent the water column temperature and salinity within the region, the monthly temperature and salinity for 25 depth layers was obtained from the World Ocean Atlas 2013 database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Center for Oceanography (Levitus et al. 2013).

The World Ocean Atlas 2013 is a set of objectively analysed (1° grid) fields of in situ parameters (e.g. temperature, salinity and dissolved oxygen) at standard depth levels for annual, seasonal, and monthly periods for the global oceans. The dataset represents the largest collection of restriction-free ocean profile data available internationally. Locarnini et al. (2013) and Zweng et al. (2013) provide discussion regarding the temperature and salinity data as part of the World Ocean Atlas 2013 database.

Table 9 show the monthly mean sea surface temperature and salinity values derived from the World Ocean Atlas 2013 database.

The water temperature and salinity values from the World Ocean Atlas 2013 database compared well to collected data by Fugro as part of the Barossa marine studies program (Fugro 2015).

Table 9 Seasonal sea surface temperature and salinity per month at the Barossa offshore development area

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (˚C)	29.5	28.5	28.8	29.4	28.8	27.1	26.8	26.9	27.1	28.1	29.7	30.4
Salinity (ppt)	34.4	34.3	34.1	34.1	34.1	34.1	33.6	33.5	34.4	34.4	34.5	34.6

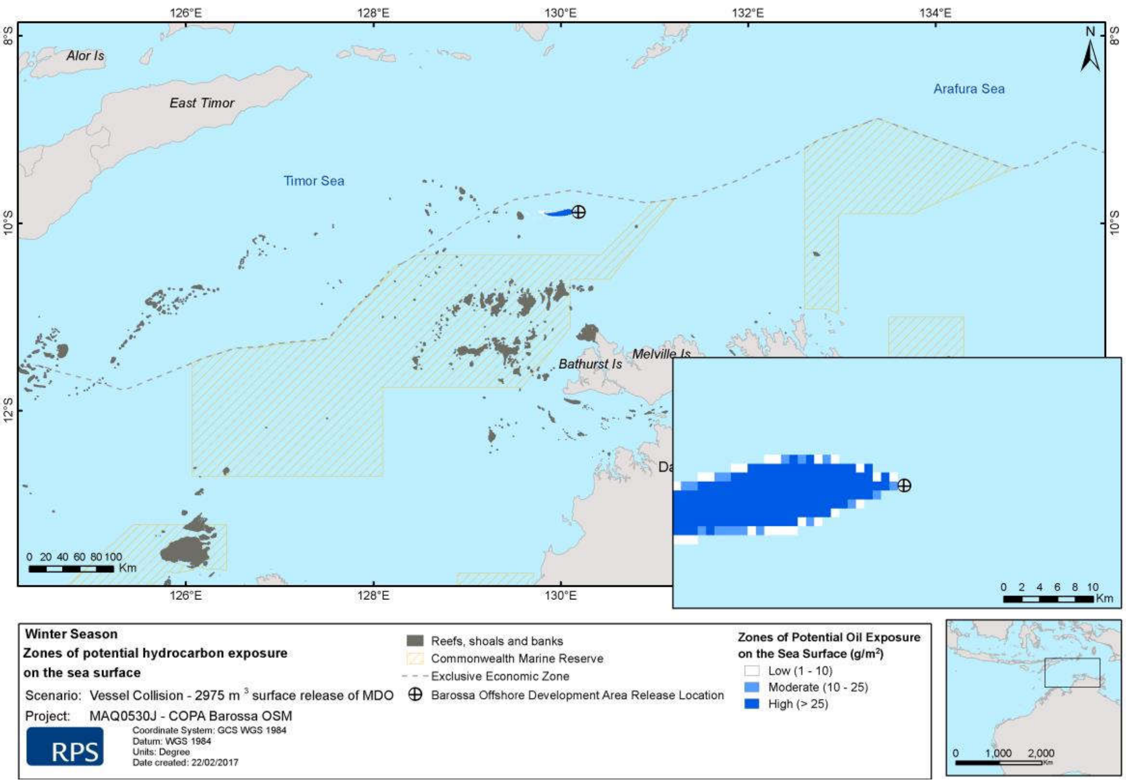
2.5 Stochastic modelling

As hydrocarbon spills can occur during any set of wind and current conditions, a stochastic modelling process was applied to all scenarios. This involved SIMAP being applied to repeatedly simulate the defined spill scenarios using the same spill information (e.g. release location, spill volume, duration and hydrocarbon type) but with varied start dates and times. This ensured that each spill was exposed to different wind and current conditions. A hundred single spill trajectories were simulated per season per scenario. During each simulation, the model records the grid cells exposed by the spill trajectory, as well as the time elapsed.

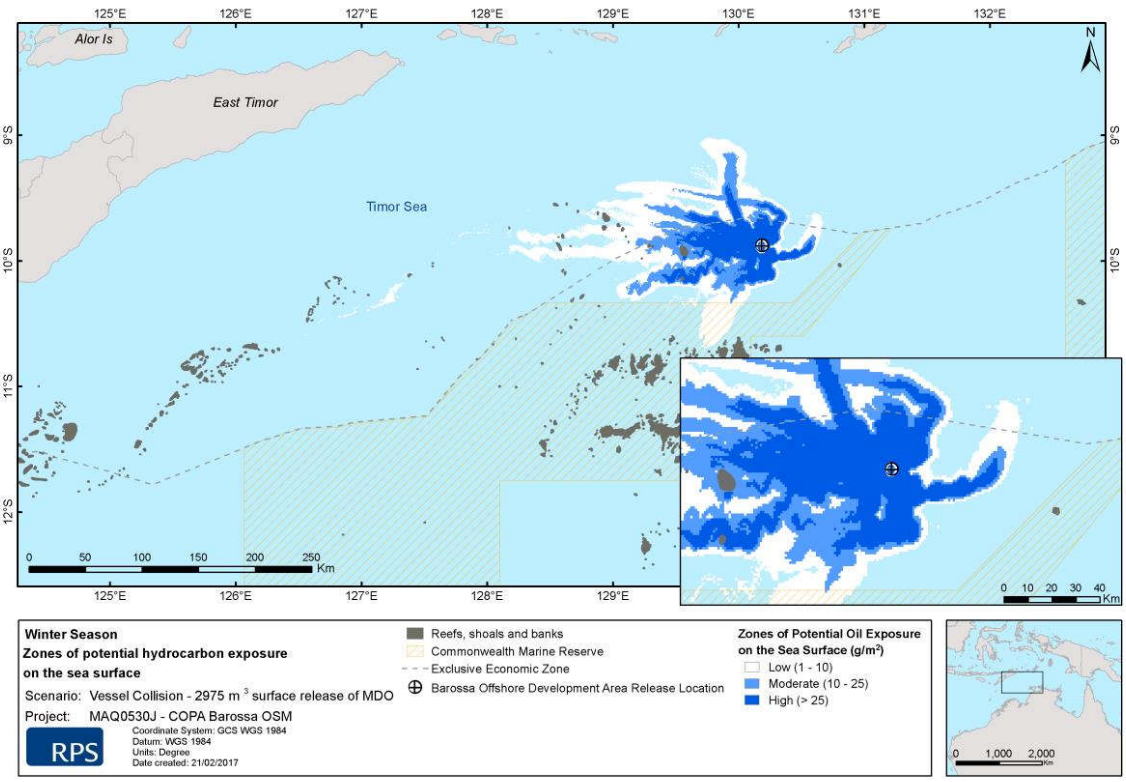
Results of the repeated simulations were then statistically analysed and mapped to define contours around the release location. The stochastic model output provides a summary, based on the collective assessment of the behaviour of all 100 individual trajectories, for each scenario and each season. This equates to 1,800 spill trajectories for the entire assessment (i.e. all scenarios and seasons).

It is important to note that in interpreting the stochastic modelling, the results are calculated independently for each grid cell from many simulations (i.e. 100 single spill trajectories per season). Therefore, the stochastic modelling plots do not show the extent of exposure that would be expected from any single release; rather the likelihood or probability of exposure to a grid cell above a specified threshold. For example, a cell with a probability of 25%, indicates that of the 100 individual spill trajectories, 25 passed over that particular model grid cell equal to or greater than the specific threshold.

As the stochastic model provides a summary of all trajectories run for each scenario and each season, the potential extent and duration of exposure from an individual spill would be significantly smaller, shorter and unlikely to extend simultaneously over vast areas (with the exception of a long-term well blowout). An example of the difference in results between a single spill trajectory (i.e. deterministic modelling) and stochastic modelling outputs for the same scenario (2,975 m^3 surface release of marine diesel over six hours during winter conditions; Scenario 2) is shown in Figure 25.



a) Deterministic modelling outputs – potential areas of sea-surface exposure (at varying thresholds) from a single spill trajectory



b) Stochastic modelling outputs – potential areas of sea-surface exposure (at varying thresholds) calculated from 100 spill trajectories

Figure 25 Comparison of deterministic and stochastic spill modelling results

2.6 Hydrocarbon properties

Four different hydrocarbons were used as part of the modelling study; MDO, Barossa condensate, HFO and IFO-180. The different hydrocarbons have varying physical and chemical properties which determine the way it will behave in the marine environment.

Table 10 and Table 11 show the physical characteristics and boiling point ranges for each hydrocarbon, respectively. The classification of hydrocarbon property category and hydrocarbon persistence classification were derived from Australian Maritime Safety Authority (AMSA 2012) guidelines. The classification is based on a hydrocarbons specific gravity in combination with relevant boiling point ranges.

Table 10 Physical properties for the hydrocarbons modelled

Properties	MDO	Barossa condensate	HFO	IFO-180
Density (kg/m^3)	829 (at 25 ºC)	796.6	974.9 (@ 25°C)	947.0 (at 5°C)
API	37.6	51.6	12.3	17.9
Dynamic viscosity (cP)	4 (at 25 ºC)	0.766 (at 25°C)	3,180 (@ 25°C)	2,324 (at 15°C)
Pour point (ºC)	-14	-40	7	24
Hydrocarbon property category	Group III	Group I	Group IV	Group IV
Hydrocarbon property classification	Persistent (medium)	Non-persistent	Persistent (heavy)	Persistent (heavy)

Table 11 Boiling point ranges for the hydrocarbons modelled

Characteristic/ Hydrocarbon type	Volatiles (%)	Semi-volatiles (%)	Low volatiles (%)	Residual (%)
Boiling point (°C)	<180	180–265	265–380	>380
	Non-persistent			Persistent
MDO	6	35	54	5
Barossa condensate	57	22	14	7
HFO	1.0	4.9	11.3	82.8
IFO-180	1.0	14.4	20.8	63.8

MDO

MDO is a mixture of volatile and persistent hydrocarbons with low viscosity. When released to the marine environment it will spread quickly and thin out to low thickness levels, thereby increasing the rate of evaporation. Due to its chemical composition, up to 60% will generally evaporate over the first two days depending upon the prevailing conditions and spill volume. Approximately 5% is considered “persistent hydrocarbons”, which are unlikely to evaporate and will decay over time.

The MDO also has a strong tendency to entrain into the upper water column (0 m–20 m) (and consequently reduce evaporative loss) in the presence of moderate winds (> 10 knots) and breaking waves. However, diesel re-surfaces when the conditions calm.

Figure 26 illustrates the predicted weathering and fates of a 10 m^3 surface release of MDO (Scenario 1) under three constant wind speeds (5, 10 and 15 knots). Figure 27 illustrates the predicted fates and weathering graph of a 2,975 m^3 surface release of MDO (Scenario 2) under the same three constant wind speeds.

For each spill volume (Scenarios 1 and 2), the fates and weathering graphs showed the MDO displayed similar behaviour. The MDO has a strong tendency to entrain into the upper water column (typically the top 0 m–20 m layer) in the presence of winds above 10 knots. Once the MDO enters the water column (i.e. penetrates the sub-surface) it can remain there for long periods of time under persistent winds, which in turn delays evaporation.

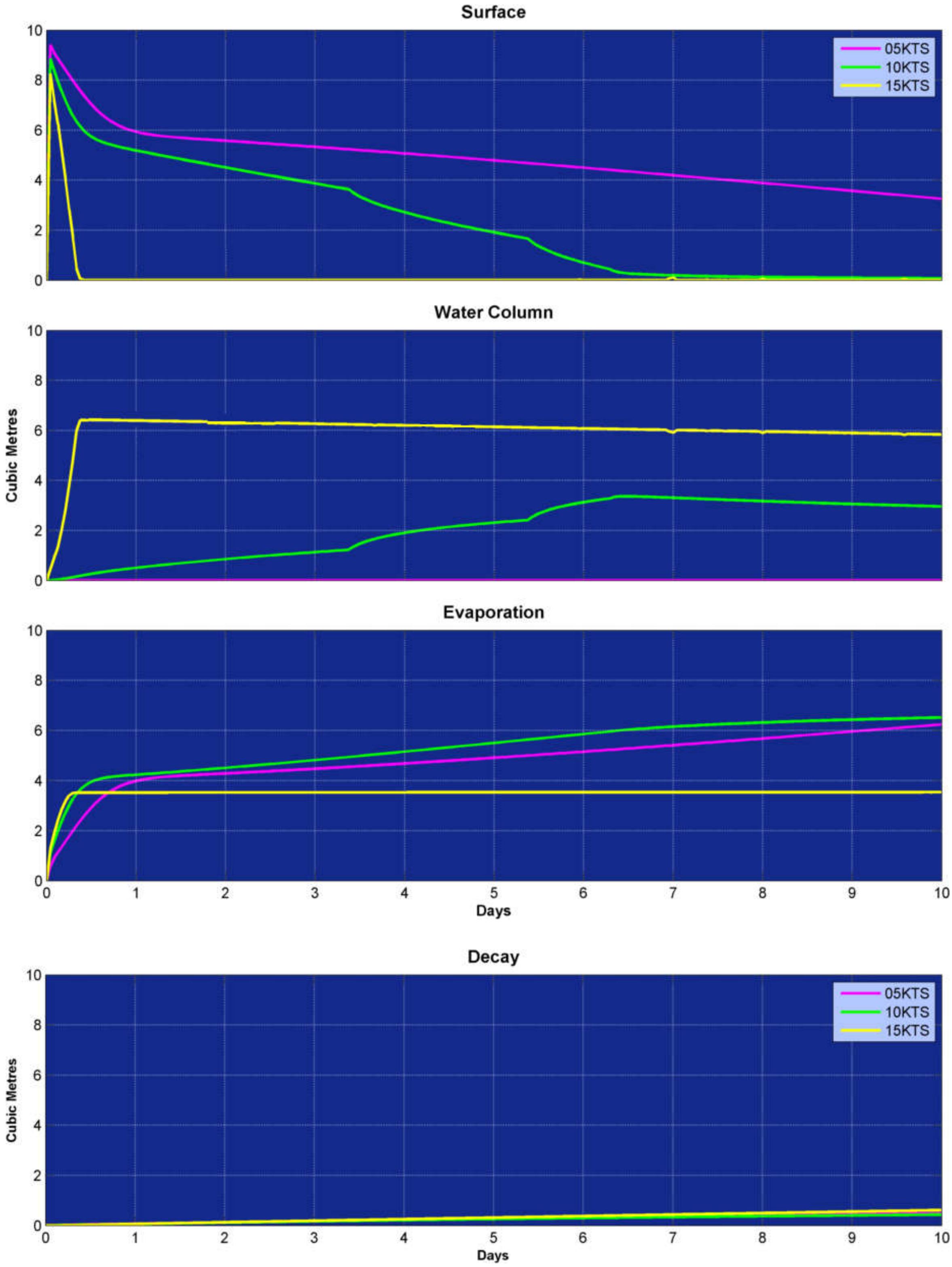


Figure 26 Weathering and fates graph, as a function of volume, for an instantaneous 10 m^3 surface release of MDO tracked over 10 days, under 5, 10 and 15 knots constant wind speeds.

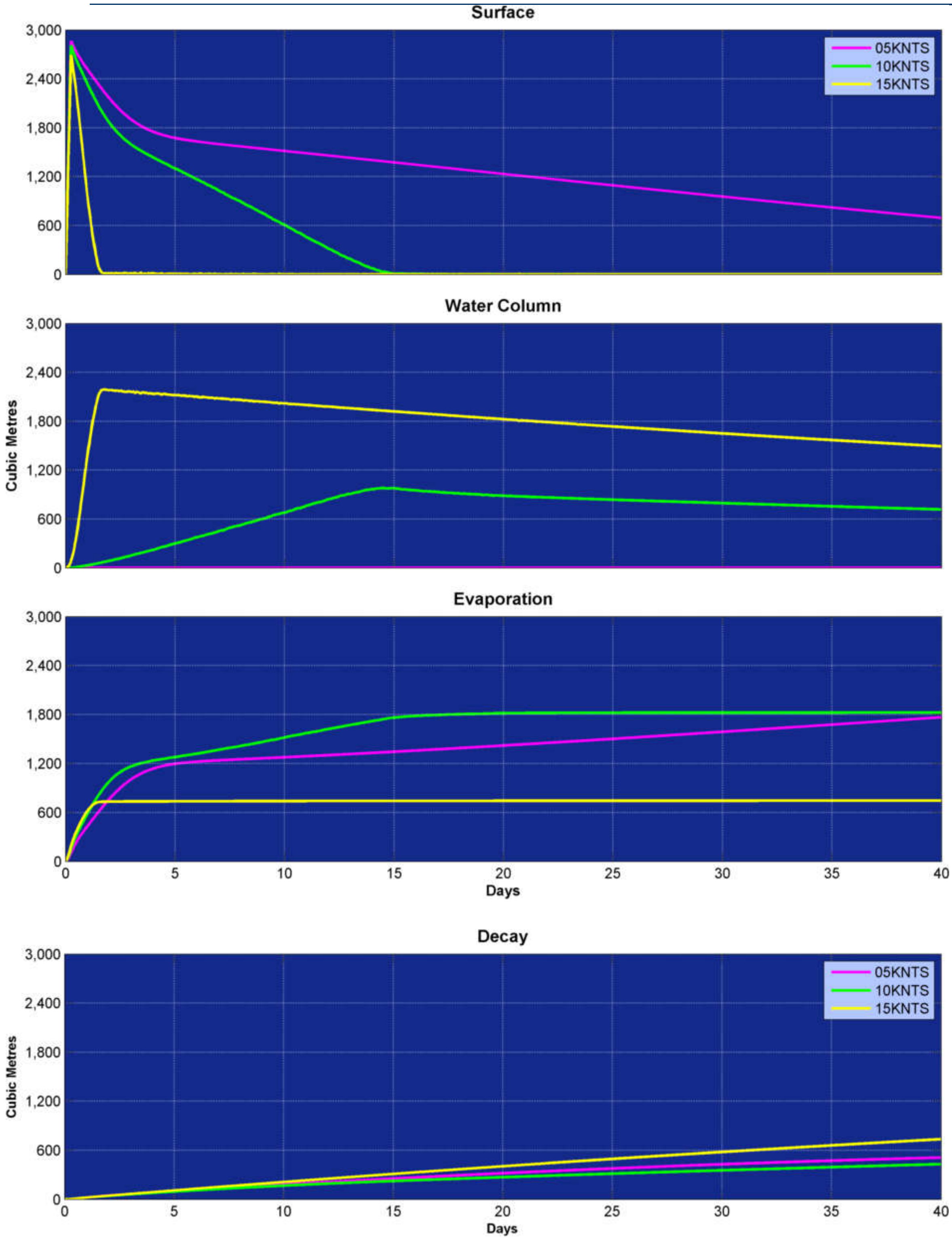


Figure 27 Weathering and fates graph, as a function of volume, for a 2,975 m³ surface release of MDO over 6 hours tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

Barossa condensate

The physical-chemical properties of Barossa condensate were based on an assay obtained during the 2013/2014 Barossa appraisal drilling campaign. The assay is considered to be representative of the reservoir characteristics of the Barossa field (i.e. unprocessed, 'volatile enriched' condensate) and the composition used to determine the weathering characteristics of the Barossa condensate.

The condensate is characterised by a low viscosity and is considered a Group I oil (non-persistent), as per the grouping classification presented by AMSA (2015). If spilt on the sea surface, the condensate would rapidly spread and thin out resulting in a large surface area of hydrocarbon available for evaporation. The volatile component of Group I oils (non-persistent) tend to dissipate through evaporation within a few hours (ITOPF 2015). Based upon the Barossa condensate assay (boiling point range, Table 11), up to 57% of the hydrocarbon would evaporate over the first few hours or day, with up to 79% evaporated after a few days when on the sea surface. Only 7% of the condensate is considered persistent, which would eventually breakdown due to the decay. Barossa condensate released to the sea surface may also become entrained into the water column in the presence of moderate winds (above 10 knots) and in turn breaking waves, however, it would re-surface under calm conditions (less than 10 knots).

Figure 28 displays the predicted weathering and fates of the 19,400 m^3 surface release of Barossa condensate, under three constant wind speeds. When released on the surface, the condensate is observed to entrain under wind speeds greater than 10 knots. Condensate on the sea surface is shown to evaporate quicker during winds of 10 knots or less and is not expected to persist on the sea surface for extended amounts of time.

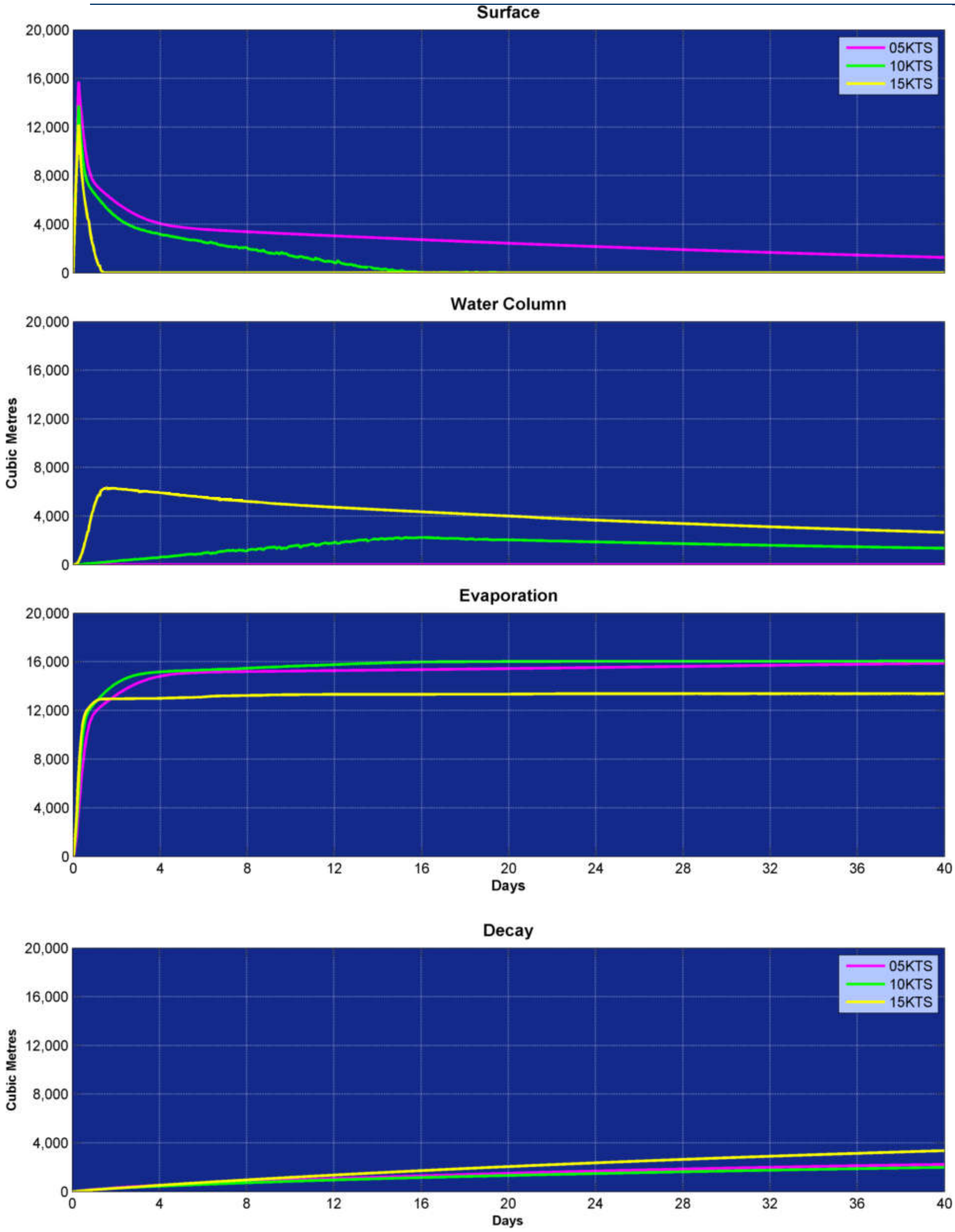


Figure 28 Weathering and fates graph, as a function of volume, for a 19,400 m³ surface release of Barossa condensate over 6 hours tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

During a well blowout, the gas and condensate is typically released at the seabed into the water column as a hot plume under high pressure. It will initially behave like a jet, which dissipates in the water column over a short distance (<5 m). Following this phase, the buoyancy of the gas and condensate mixture relative to the surrounding waters controls the plume rise until it penetrates the surface waters or loses its momentum. At this point, the far-field model SIMAP is used to simulate the rise of the individual condensate droplets due to their own buoyant nature.

Modelling for the well blowout scenario (scenario 4) showed that the condensate would be expected to separate into droplets of variable sizes between 18.4 µm and 92.1 µm. The minimum time for the condensate droplets to reach the surface at concentrations above the minimum sea surface threshold (1 g/m^2) was approximately one-hour post release. However, due to varying wind and current conditions, smaller condensate droplets can remain in the water column for days or weeks before reaching the sea surface. Therefore, evaporation rates would initially be expected to be rapid during the early phase of the release scenario, where larger droplets surface, and then decline over time.

On release from the seabed, the plume is predicted to rise through the water column (average velocity of approximately 3 m per second) and rupture at the sea surface (Table 12). Therefore, the concentration of entrained hydrocarbons is predicted to be greatest in the surface layer and lowest at the seabed. The maximum core diameter of the plume was predicted to be approximately 31 m.

Table 12 Predicted near-field plume dynamics for Scenario 4 (long-term well blow out)

Variable	Scenario 4 - Well Blowout
Average plume rise velocity (m/s)	3.0
Maximum plume rise velocity (m/s)	5.7
Plume rise time in seconds (until plume collapse)	81
Maximum plume core diameter (m)	31
Plume trapping depth below the sea surface (m)	Surface

Figure 29 illustrates predicted weathering and fates of the 210 m^3 subsea release of Barossa condensate, under three constant wind speeds. The graph shows that as wind speed increased, a larger volume of hydrocarbon remained entrained in the water column, and consequently less evaporation occurred. Wind speed was observed to have a minimal effect on the volume of condensate floating on the sea surface because the condensate rapidly evaporates when exposed to the atmosphere.

On weathering, the Barossa condensate would undergo a series of changes to appearance, colour and phase state. Within 24 hours of release, the remaining condensate would be expected to be almost semi-solid at average sea surface temperature. As weathering continues, the weathered residues of the Barossa condensate would be mostly in the form of paraffins, which would remain afloat as the hydrocarbon spreads out and thins. As the residues become solid, they would form thin, clear sheets with patches of white crystalline ‘pancakes’ which would then begin to break up into small, white waxy flakes due to the action of the waves and wind over time.

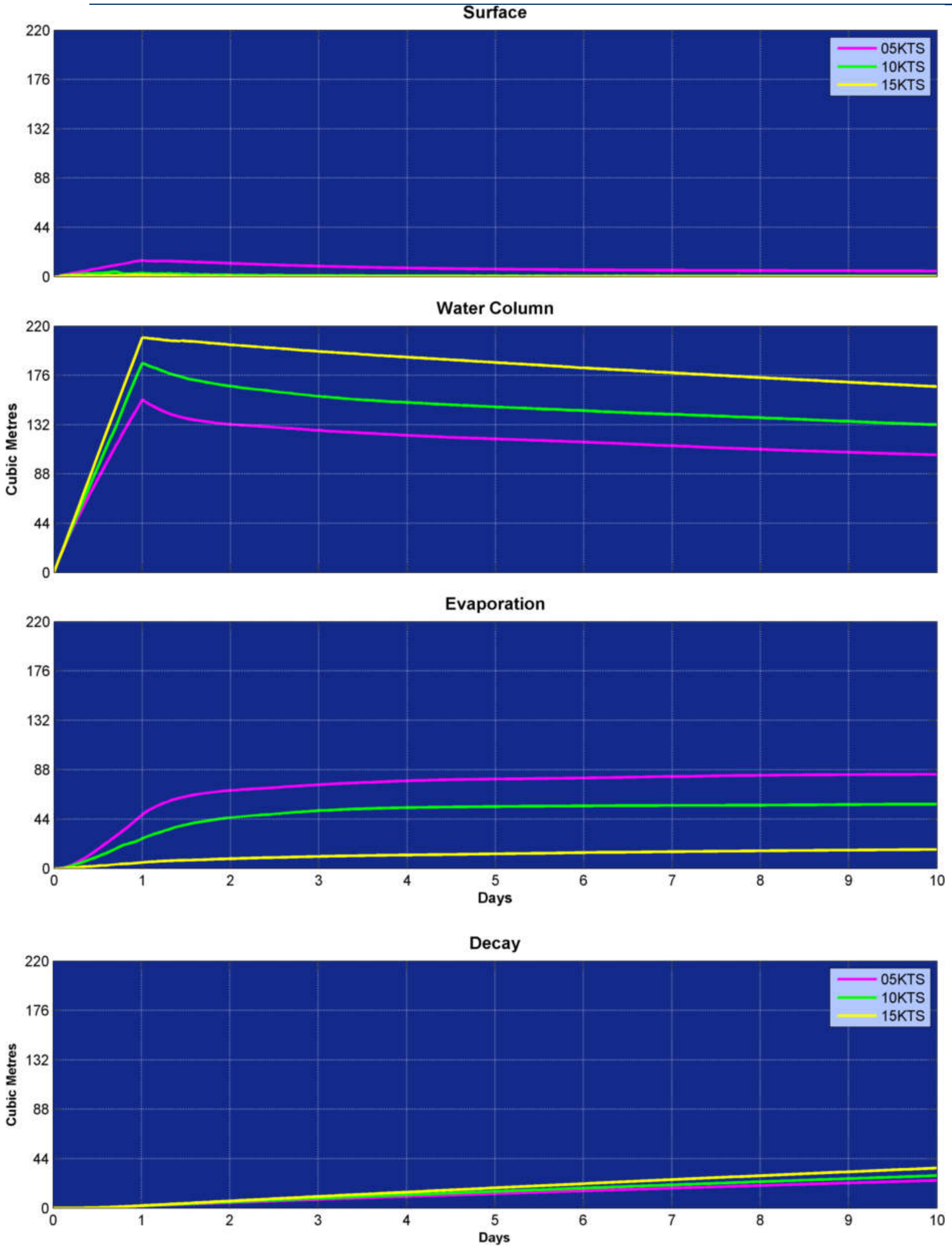


Figure 29 Weathering and fates graph, as a function of volume, for a 210 m^3 subsea release of Barossa condensate over 24 hours tracked over 10 days, under 5, 10 and 15 knots constant wind speeds.

Hydrocarbons that cause most of the "aquatic toxicity" are generally the smaller aromatic and soluble components of hydrocarbon (one ring and two ring aromatics) or the polyaromatic hydrocarbons (PAHs). The low volatility fraction of the Barossa condensate contains very low levels of aromatics in the three ring and above PAHs according to the assay. Therefore, the weathered residues of the condensate are not considered to present an ecotoxological threat in the water column.

A comparative analysis of the physical characteristics and boiling point ranges of the Barossa and Caldita condensates were undertaken to assess if the properties, and therefore modelling results, were comparable. The analysis of the two condensates is presented in Table 13 and Table 14 shows that the key physical-chemical properties are very similar and, consequently, the behaviour, fate, weathering and toxicity of the condensates are highly comparable. As part of the analysis, the results of the Jacobs (2017) Barossa condensate ecotoxicity assessment were reviewed to assess the comparability of the potential toxicity impacts from unweathered and weathered Barossa or Caldita condensate. Given the similarity of the condensates, especially the benzene, toluene, ethylbenzene, and xylene (BTEX) compounds which are known to contribute to toxicity (Barossa condensate – approximately 6.9% weight and Caldita condensate – approximately 5.3% weight), the review concluded that the Barossa ecotoxicity study is representative of Caldita condensate. Therefore, the modelling results for the Barossa condensate scenarios are considered to be representative of potential modelling scenarios involving Caldita condensate.

Table 13 Physical properties for Barossa and Caldita condensates

Properties	Barossa condensate	Caldita condensate
Density (kg/m^3)	796.6	754.2
API	51.6	48-50.5
Dynamic viscosity (cP)	0.766 (at 25°C)	-
Pour point (ºC)	-40	-
Hydrocarbon property category	Group I	Group 1
Hydrocarbon property classification	Non-persistent	Non-persistent

Table 14 Boiling point ranges for Barossa and Caldita condensates

Characteristic/ Hydrocarbon type	Volatiles (%)	Semi-volatiles (%)	Low volatiles (%)	Residual (%)
Boiling point (°C)	<180	180–265	265–380	>380
	Non-persistent			Persistent
Barossa condensate	57	22	14	7
Caldita condensate	45	30	13	12

HFO

HFO is characterised by a very high density at 974.9 (API Gravity of 12.3) and a high dynamic viscosity (3,180 cP (@ 25ºC). It is comprised of a high percentage of persistent components (82.8%), which will not evaporate. When spilt at sea the HFO will initially remain as a liquid as sea surface temperatures are above its pour point during all seasons. The volatile components (1%) are immediately lost via evaporation and the physical properties will change quickly as the lighter more fluid components evaporate and disperse by the action of wind and waves. The residual component (approximately 83%) is expected to become semi-solid to solid at ambient temperatures and is susceptible to decay overtime. Previous weathering tests with HFO used as bunker fuels have shown that both the pour point and the viscosity of the oil increased with time (by an average of two orders of magnitude within 96 hours of weathering). Once the pour point of oil exceeded the seawater temperature (within 9-12 hours during all seasons) the oil weathered to a point where mostly solid non-spreading oil remained (up to 70% of bunker fuel remained as a solid residue even after the most extreme weathering tests).

Laboratory tests with Bunker C Crude oil (Fingas et al. 2002, Fingas and Fieldhouse 2004) which has similar physical properties to the HFO modelled in this study have shown that HFO does not form stable emulsions. Rather, when HFO is spilt at sea it takes up water very rapidly over a short energy range and the stability of the water-oil mixture remains the same in that it does not stabilise with increasing energy. This behaviour is consistent with entrained water in oil, where spilt oil will first appear as a black viscous liquid with large water droplets and within one week will become separated into oil and water as water energies abate.

The toxic potential of weathered HFO is low in comparison to other crudes, MDO and condensates as weathered oil is insoluble and the bioavailable portion of the oil is soon lost through evaporation. Solid residues can persist in the marine environment for extended periods and its longevity is dependent on its unique physio-chemical properties. The heaviest fractions (>C20) often break into discrete patches and may float or sink depending on density relationships and become incorporated into soils or sediments (American Petroleum Institute 2012). Selective biodegradation can also deplete hydrocarbons on sediments and on the sea surface overtime (Lee et al. 2003). Direct consumption of the residual tar patties or contaminated sediment poses the greatest risk to macrofauna and would present a greater threat for shallow coastal embayments with concentrated populations and coastal vegetation.

Figure 30 illustrates predicted weathering and fates of the surface release of HFO, under three constant wind speeds. As the graph demonstrates, the wind speed has very little influence on the weathering of the HFO and decay is the major source of removal of hydrocarbon from the sea surface.

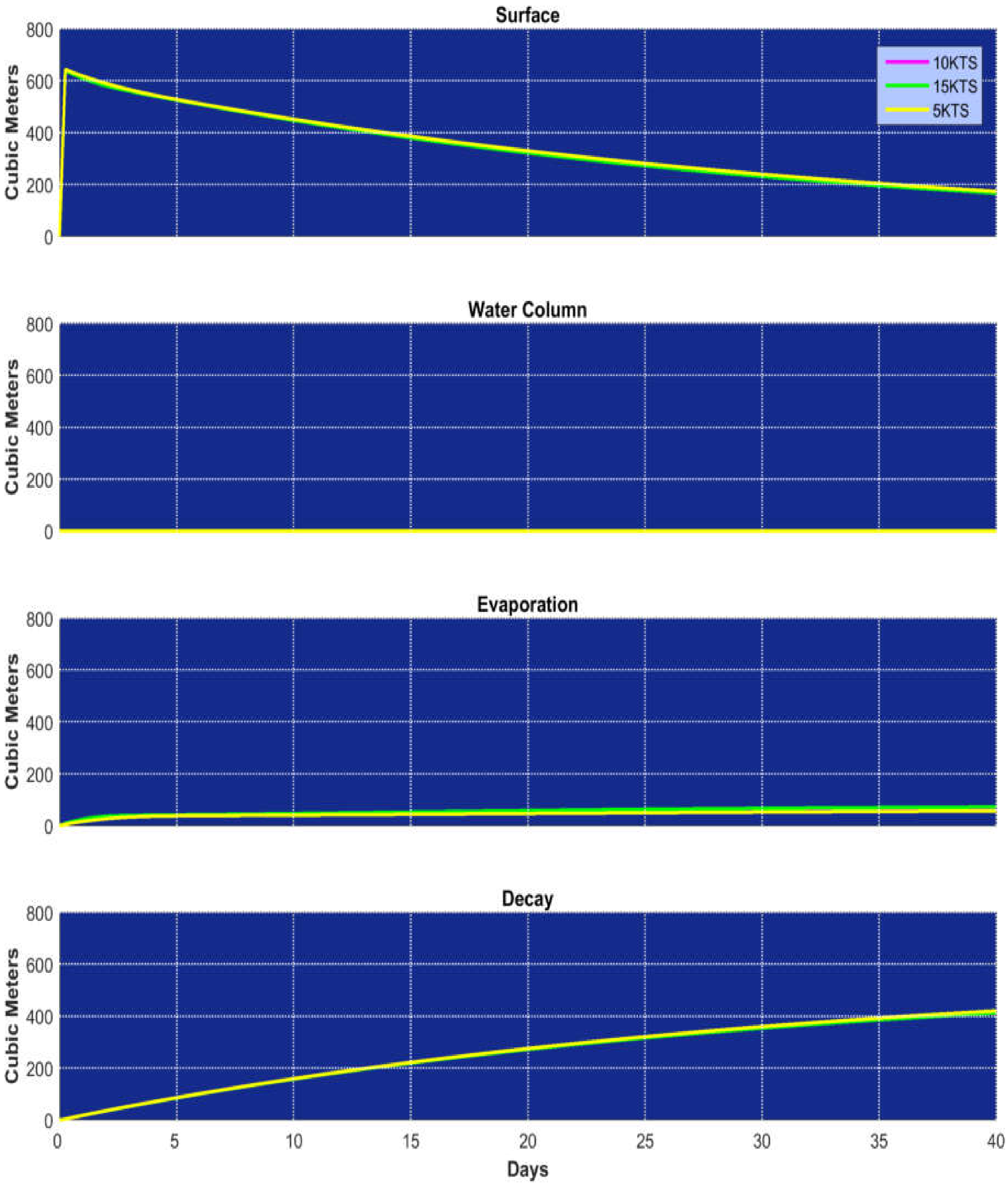


Figure 30 Weathering and fates graph, as a function of volume, for a 650 m^3 surface release of HFO over 6 hours tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

IFO-180

The IFO-180 has a high density (947 kg/m^3 and API of 17.9) and a high viscosity (2,324 cP). It consists mainly of low volatile (20.8%) and persistent hydrocarbons (63.8%). If released to the marine environment the light volatiles (1%) are rapidly lost via evaporation while the residual component (approximately 64%) is expected to become semi-solid to solid at ambient temperatures. IFO-180 does not tend to entrain in the upper water column based on the hydrocarbon characteristics.

IFO can form stable or meso-stable water-in-oil emulsions in which seawater droplets become suspended into the oil matrix (Fingas and Fieldhouse 2004). This process requires physical mixing (i.e. wave action) with the stability of the emulsion influenced by the properties of the hydrocarbon product, including viscosities and asphaltene and resin content. Stable emulsions generally have an average water content of approximately 80% after 24 hours and have been shown to remain stable for up to four weeks under laboratory and test tank conditions (Fingas and Fieldhouse 2004). Meso-stable water-in-oil emulsions have an average water content of around 70% after 24 hours which decreases to approximately 30% after one week (Fingas and Fieldhouse 2004). Meso-stable emulsions generally become unstable within three days, as shown under laboratory conditions. Emulsification of IFO-180 will affect the spreading and weathering of the oil and increase the volume of oily material. If not within an emulsion state, the decay of IFO-180 is more rapid in comparison to condensates and marine diesel as microbial decay is generally faster for hydrocarbons with higher viscosity.

The toxic potential of IFO-180 is largely dependent on the properties it has been blended with but generally contains <10% distillate with the remaining 90% composed of HFOs. The volatile and soluble components include those that are responsible for producing most of the aquatic toxicity due to its bioavailability to marine organisms. Thus Barossa condensate and MDO are considered to have a higher aquatic toxicity potential in comparison to IFO-180. However non-persistent components are short-lived and susceptible to evaporation and degradation. The weathered portion of IFO would behave similar to HFO. The residual components would eventually become insoluble in seawater and end up adhered to sediment or biota reducing the risk of acute toxicity.

Figure 31 illustrates predicted weathering and fates of the IFO-180, under three constant wind speeds. Under all three wind speeds tested, the evaporative loss was very similar. The graph demonstrates the highly persistent and viscous nature of the oil, with entrainment only occurring during 15 knot wind conditions. Decay of IFO-180 is more rapid in comparison to condensates and MDO as microbial decay is generally faster for hydrocarbons with higher viscosity.

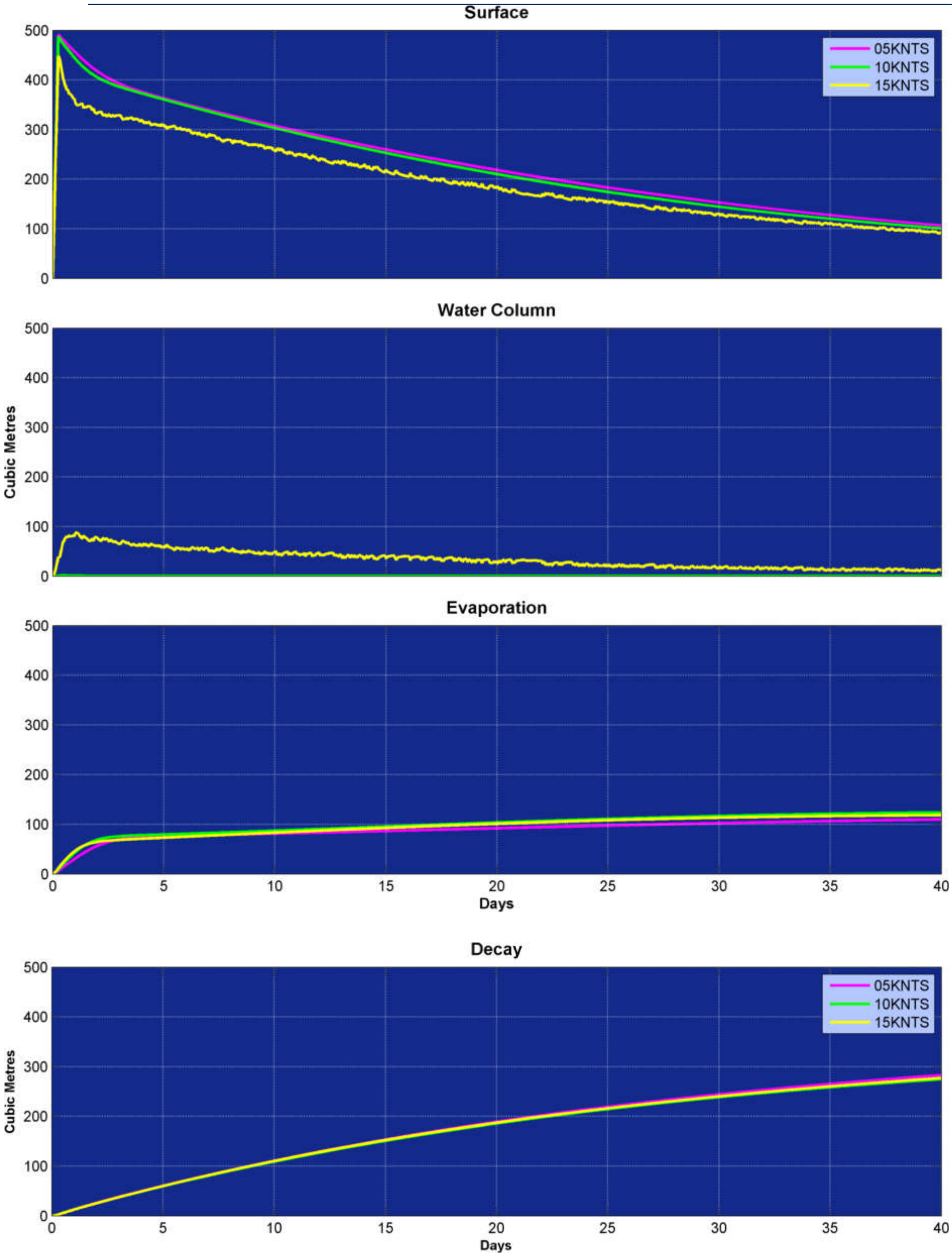


Figure 31 Weathering and fates graph, as a function of volume, for a 500 m^3 surface release of IFO-180 tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

2.7 Model settings and assumptions

Table 15 provides a summary of the hydrocarbon spill model settings and assumptions. The simulation lengths were carefully selected for each scenario based on extensive sensitivity testing. During the sensitivity testing process, sample spill trajectories are run for longer than intended durations for each scenario. Upon completion of the spill trajectories, the results are carefully assessed to examine the persistence of the hydrocarbon (i.e. whether the maximum evaporative loss has been achieved for the period of time modelled; and whether a substantial volume of hydrocarbons remain in the water column (if any)) in conjunction with the extent of sea surface exposure based on reporting thresholds. The persistence of the hydrocarbons on the sea surface and entrained within the water column is based on several factors including the nature of release (duration, volume and type (subsea or surface)), residual properties of the hydrocarbon type and weathering. Once there is agreement between the two factors (i.e. the final fate of hydrocarbon is accounted for and the full exposure area is identified) the simulation length is deemed appropriate.

Table 15 Summary of the hydrocarbon spill model settings

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Scenario description	Refuelling incident	Ship collision and support vessel fuel tank rupture	Ship collision and FPSO storage tank rupture	Long term subsea well blowout	Ship collision and export tanker fuel tank rupture	Ship collision and single tank rupture from pipelay vessel
Location	Barossa offshore development area					Gas export pipeline corridor
Number of randomly selected spill start times per season	100	100	100	100	100	100
Hydrocarbon type	MDO	MDO	Barossa condensate	Barossa condensate	HFO	IFO-180
Spill volume (m^3)	10	2,975	19,400	16,833	650	500
Release type	Surface	Surface	Surface	Subsea	Surface	Surface
Release duration	Instantaneous	6 hours	6 hours	80 days	6 hours	6 hours
Simulation length	10 days	40 days	40 days	90 days	40 days	40 days
Seasons assessed	Summer season (December to February) Transitional period (March and September to November) Winter season (April to August)					
Reporting surface hydrocarbon exposure thresholds	1 g/m^2 (low exposure), 10 g/m^2 (moderate exposure) and 25 g/m^2 (high exposure)					
Reporting entrained hydrocarbon thresholds	10 ppb (low exposure), 100 ppb (moderate exposure) and 500 ppb (high exposure)					
Reporting dissolved aromatic thresholds	6 ppb (low exposure), 50 ppb (moderate exposure) and 400 ppb (high exposure)					

2.8 Sea surface and sub-surface thresholds

The SIMAP model is able to track hydrocarbons to levels lower than biologically significant or visible to the naked eye. Therefore, reporting thresholds have been specified (based on the scientific literature) to account for "exposure" on the sea surface and "contact" to environmental receptors at meaningful levels.

The thresholds for the surface and sub-surface hydrocarbons, and their correlation with the zones of exposure, are presented in Table 16. Table 16 also provides supporting justification of the thresholds applied and additional context relating to the area of influence, as assessed in the Barossa OPP.

Table 16 Sea surface and sub-surface thresholds and zones of exposure

Exposure zone	Threshold	Justification
Sea surface film threshold		
Exposure zone Low exposure (1 g/m^2–10 g/m^2)	1 g/m^2	The 1 g/m^2 threshold represents the practical limit of observing hydrocarbon sheens in the marine environment and therefore has been used to define the outer boundary of the low exposure zone. This threshold is considered below levels which would cause environmental harm and is more indicative of the areas perceived to be affected due to its visibility on the sea-surface. This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill.
Adverse exposure zone Moderate exposure (10 g/m^2–25 g/m^2)	10 g/m^2	Ecological impact has been estimated to occur at 10 g/m^2 as this level of oiling has been observed to mortally impact birds and other wildlife associated with the water surface (French et al. 1996; French-McCay 2009). The 10 g/m^2 threshold has been selected to define the moderate exposure zone and outer boundary for the adverse exposure zone. Contact within this exposure zone may result in impacts to the marine environment and is therefore considered to be within the area of influence from a hydrocarbon spill.
Adverse exposure zone High exposure (> 25 g/m^2)	25 g/m^2	The 25 g/m^2 threshold is above the minimum threshold observed to cause ecological impact. Studies have indicated that a concentration of surface oil 25 g/m^2 or greater would be harmful for the majority of birds that contact the hydrocarbon at this concentration (Scholten et al. 1996; Koops et al. 2004). Exposure above this threshold is used to define the high exposure zone and is within the adverse exposure zone. This area is also within the area of influence.
Entrained hydrocarbon threshold		
Exposure zone Low exposure (10 ppb–100 ppb)	10 ppb	The 10 ppb threshold represents the lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or is trapped against a shoreline for periods of several days or more. This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the hydrocarbon spill.
Adverse exposure zone Moderate exposure (100 ppb–500 ppb)	100 ppb	The 100 ppb threshold is considered conservative in terms of potential for toxic effects leading to mortality for sensitive mature individuals and early life stages of species. This threshold has been defined to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations.

Exposure zone	Threshold	Justification
		The 100 ppb threshold has been selected to define the moderate exposure zone and outer boundary for the adverse exposure zone. Contact within this exposure zone may result in impacts to the marine environment and is therefore considered to be within the area of influence from a hydrocarbon spill.
Adverse exposure zone High exposure (> 500 ppb)	500 ppb	The 500 ppb threshold is considered conservative high exposure level in terms of potential for toxic effects leading to mortality for more tolerant species or habitats. As discussed above, this threshold has been defined to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations (RPS APASA 2016d). The 500 ppb threshold has been selected to define the high exposure zone and is within the adverse exposure zone. This area is also within the area of influence.
Dissolved aromatic hydrocarbon threshold		
Exposure zone Low exposure (6 ppb–50 ppb)	6 ppb	The threshold value for species toxicity in the water column is based on global data from French et al. (1999) and French-McCay (2002, 2003), which showed that species sensitivity (fish and invertebrates) to dissolved aromatics exposure > 4 days (96-hour LC_{50}) under different environmental conditions varied from 6 ppb–400 ppb, with an average of 50 ppb. This range covered 95% of aquatic organisms tested, which included species during sensitive life stages (eggs and larvae). Based on scientific literature, a minimum threshold of 6 ppb used to define the low exposure zones (Engelhardt 1983; Clark 1984; Geraci and St. Aubin 1988; Jenssen 1994; Tsvetneko 1998). This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the hydrocarbon spill.
Adverse exposure zone Moderate exposure (50 ppb–400 ppb)	50 ppb	A conservative threshold of 50 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French 2002). French-McCay (2002) indicates that an average 96-hour LC_{50} of 50 ppb could serve as an acute lethal threshold to 5% of biota. The 50 ppb threshold has been selected to define the moderate exposure zone and outer boundary for the adverse exposure zone. Contact within this exposure zone may result in impacts to the marine environment and is therefore considered to be within the area of influence from a hydrocarbon spill.
Adverse exposure zone High exposure (> 400 ppb)	400 ppb	A conservative threshold of 400 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French-McCay 2002). French-McCay (2002) indicates that an average 96-hour LC_{50} of 400 ppb could serve as an acute lethal threshold to 50% of biota. The 400 ppb threshold has been selected to define the high exposure zone and is within the adverse exposure zone. This area is also within the area of influence.

LC_{50}: Median lethal dose required for mortality of 50% of a tested population after a specified test duration.

2.9 Receptors assessed

Figure 32 shows the emergent receptors assessed for surface and subsea exposure from hydrocarbons. Figure 33 to Figure 36 display islands, reefs, shoals and banks (submerged receptors) while Figure 37 displays the Commonwealth Marine Reserves (CMRs) and commercial fisheries (i.e. Timor Reef Fishery) assessed for sea surface and subsea exposure. Figure 38 displays the key ecological features (KEF) used to assess surface and subsea exposure.

When reporting subsea exposure for the Timor Reef Fishery and KEFs, the maximum depth modelled within that scenario was used. This is because the Timor Reef Fishery is associated with deep water fishing at 80 m–120 m and the KEFs are marine regions based on different benthic habitats. As such the results at the greatest depth are most relevant to these receptors.

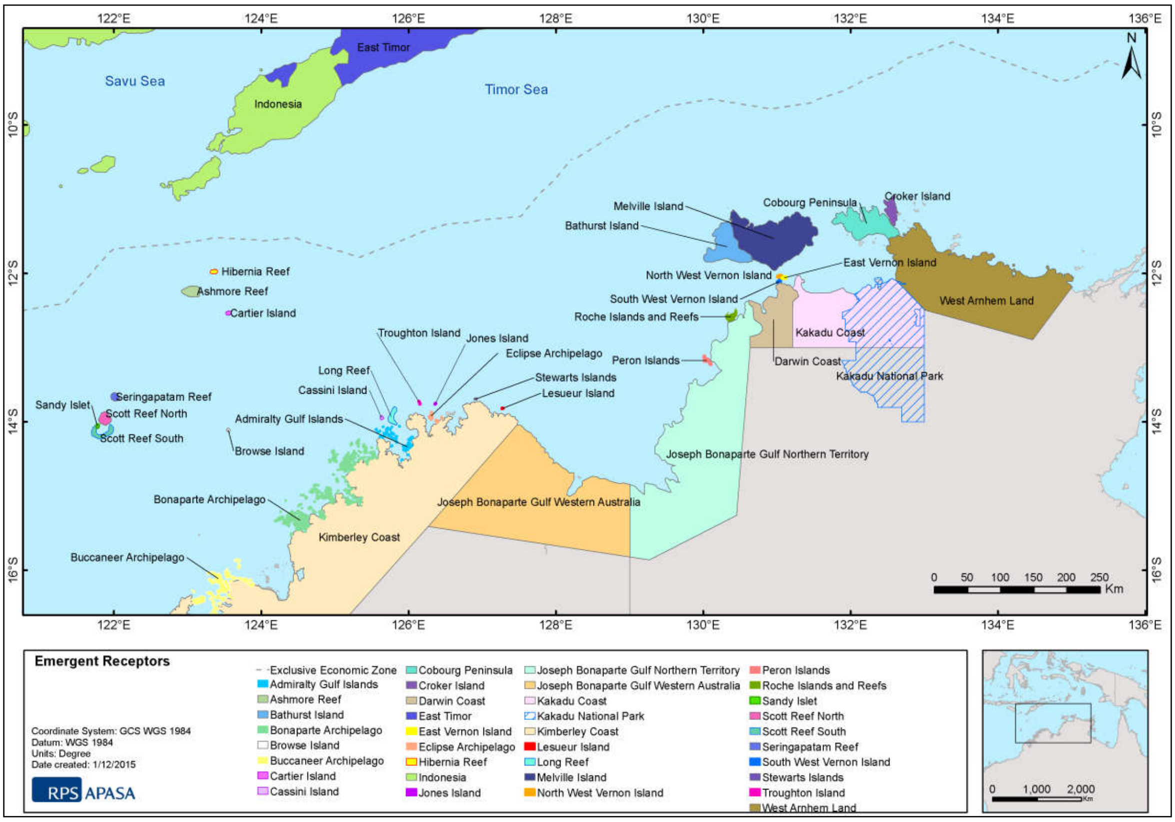


Figure 32 Coastlines (emergent receptors) assessed for surface and subsea exposure from hydrocarbons

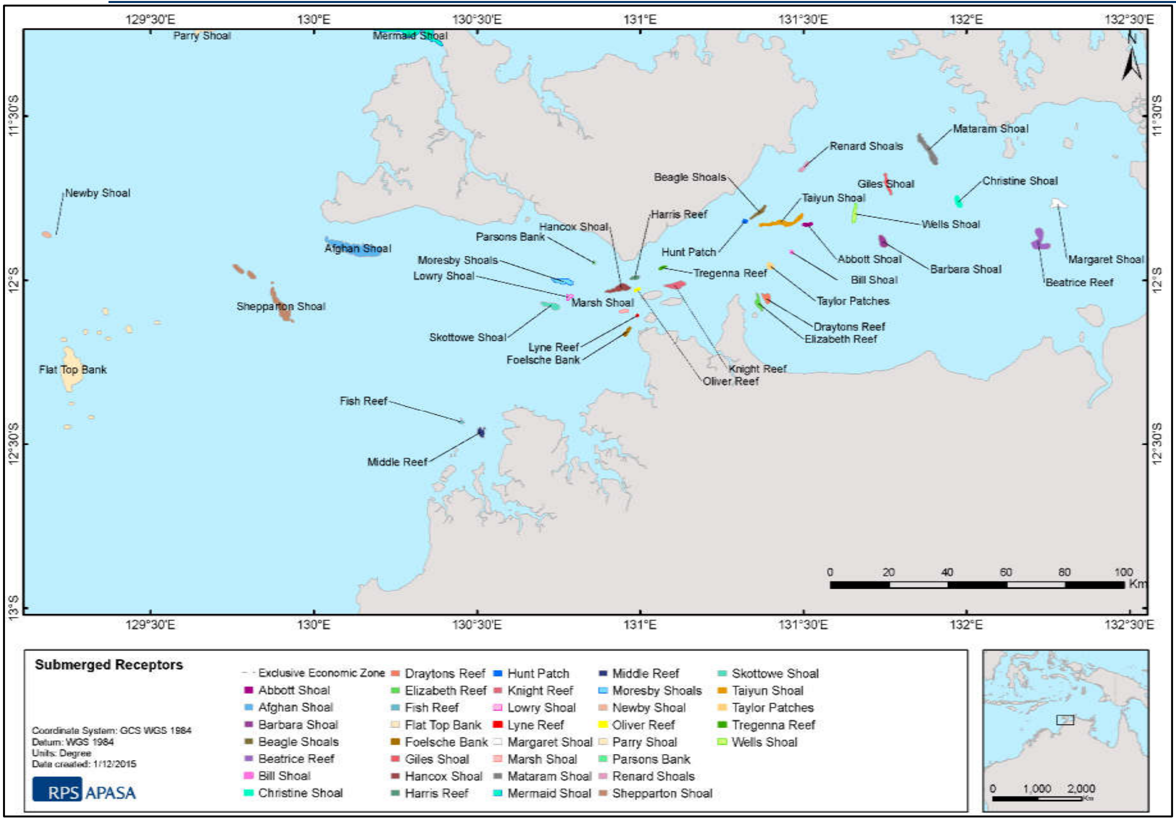


Figure 33 Van Diemen Gulf reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

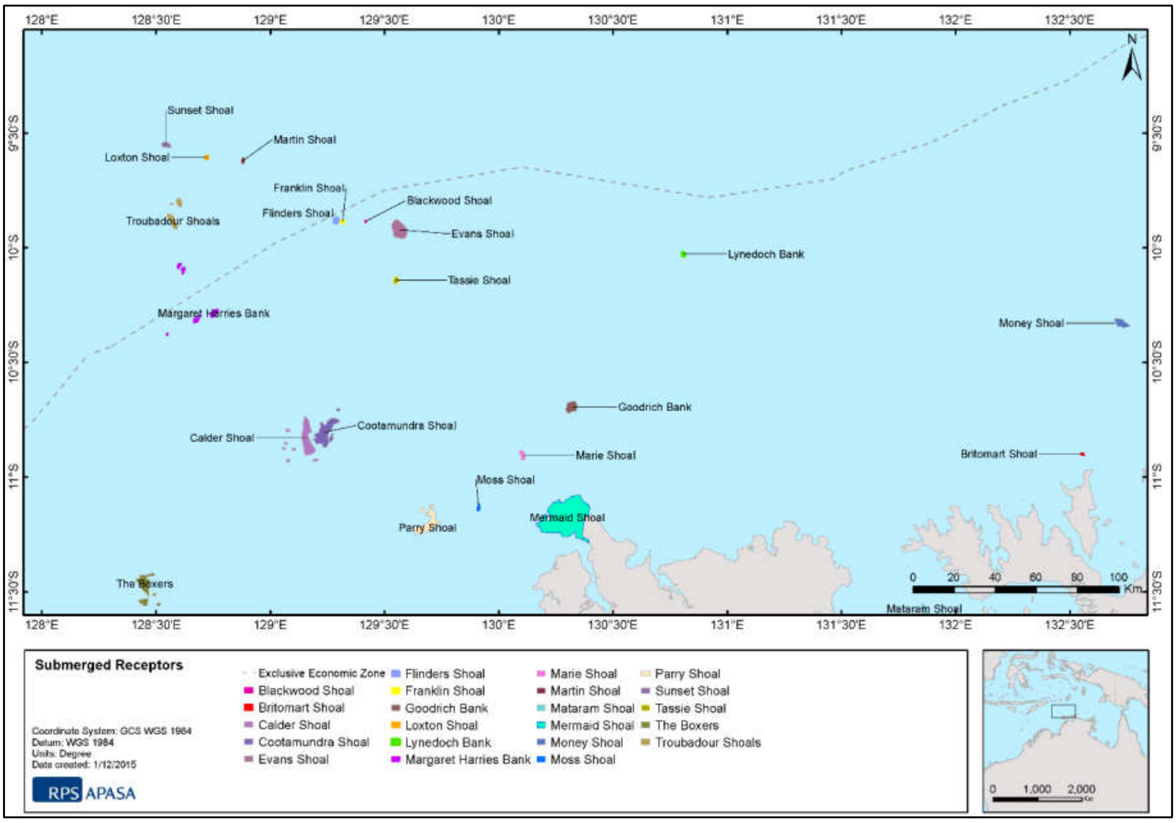


Figure 34 Northern reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

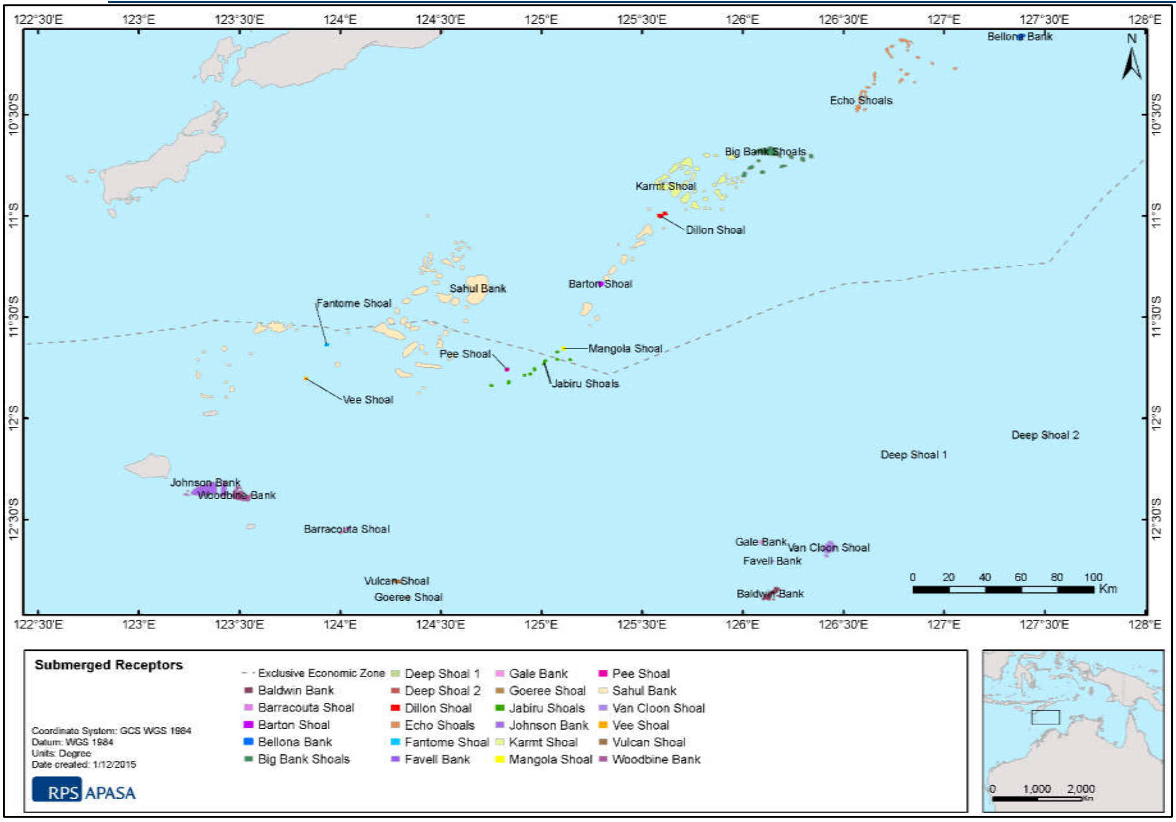


Figure 35 North-west reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

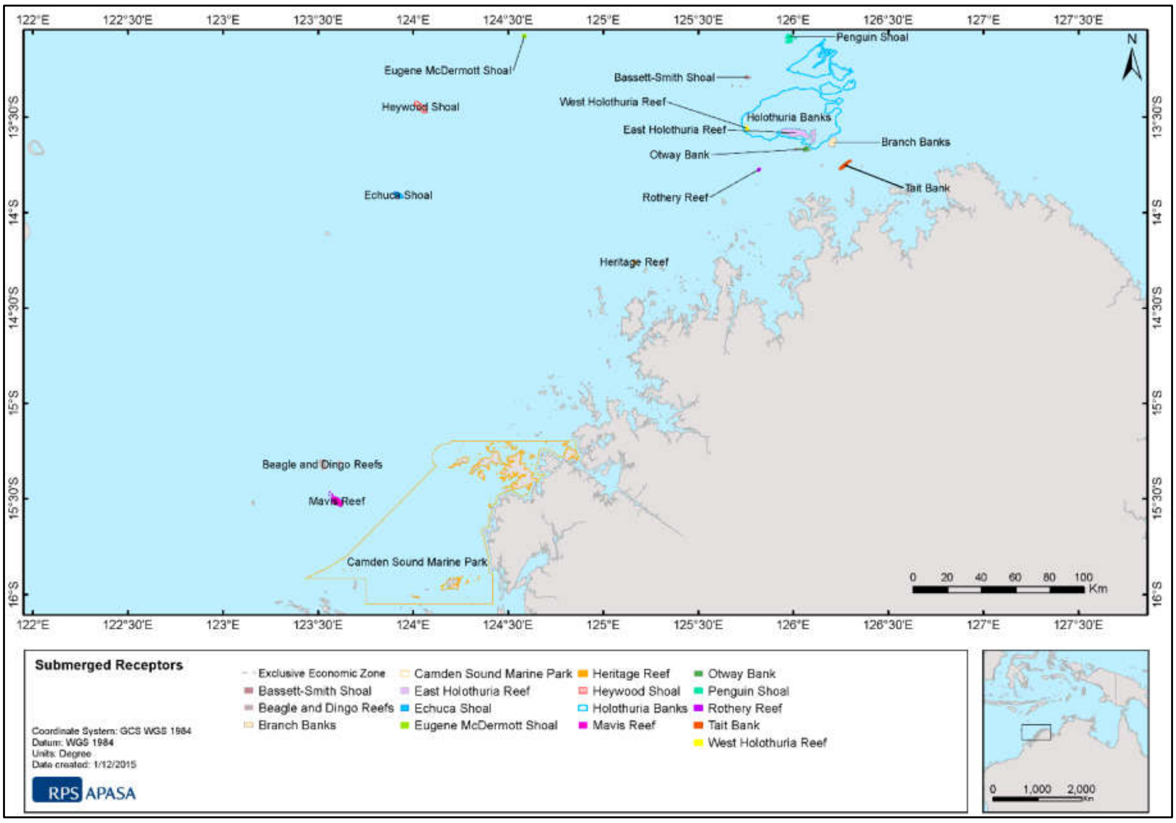


Figure 36 South-west reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

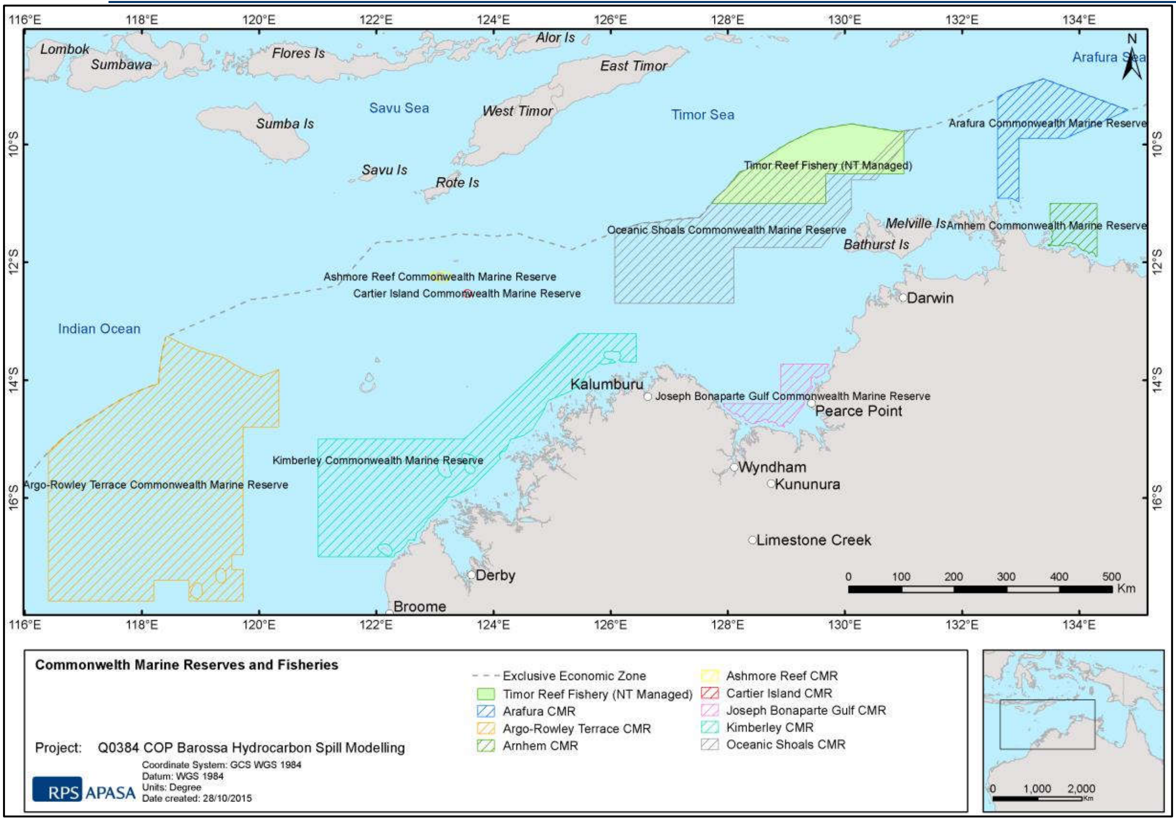


Figure 37 CMRs and Timor Reef Fishery assessed for sea surface and subsea exposure from hydrocarbons

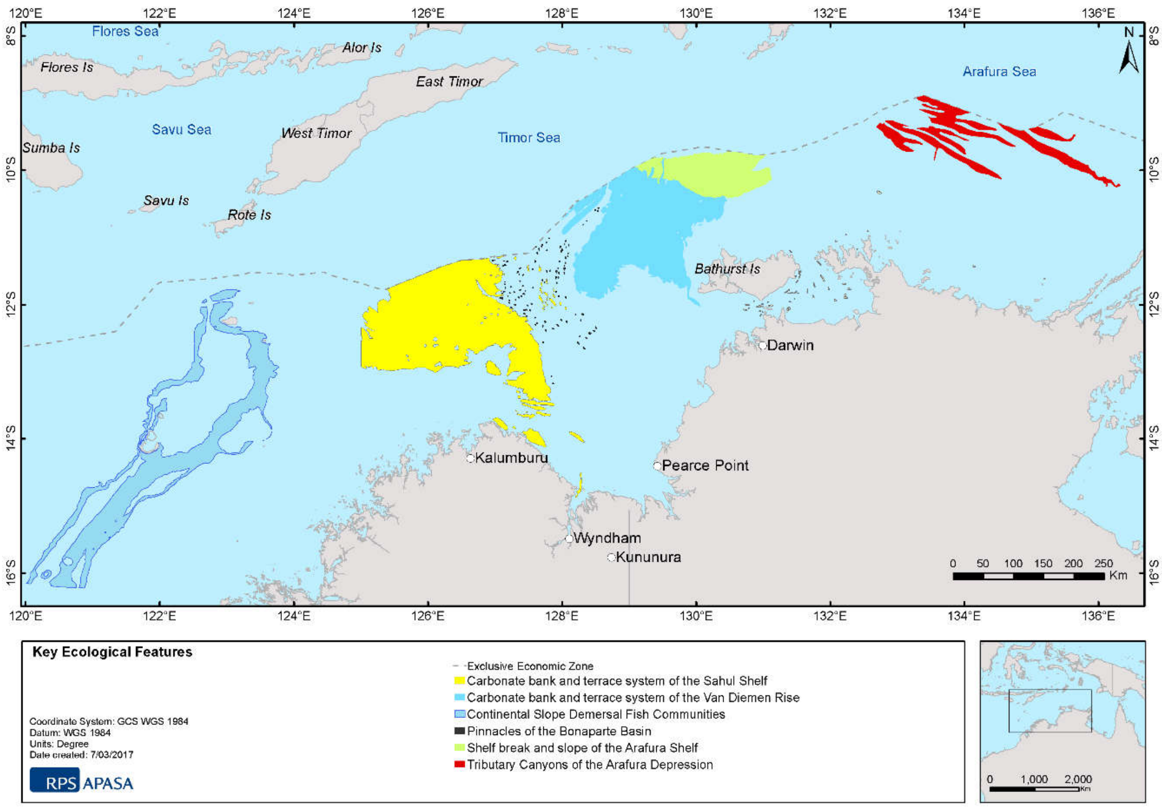


Figure 38 KEFs assessed for sea surface and subsea exposure from hydrocarbons

3. MODELLING RESULTS

A summary of the key modelling outputs for each of the maximum credible scenarios is presented in the following sections. For each scenario, results are presented in both tabular summaries and figures for sea surface, entrained and dissolved aromatic hydrocarbons for all thresholds and exposure zones (i.e. low, moderate and high). However, the up-front summary of the stochastic modelling results focusses on the moderate sea-surface, entrained and dissolved aromatic thresholds as these are considered to define the outer boundary of the adverse exposure zone, and therefore, the area that may be impacted by the spill scenario (i.e. area of influence).

The results are calculated as follows:

- probability of hydrocarbon exposure on the sea surface – is calculated by dividing the number of spill trajectories passing over a given model grid cell (above a defined threshold) by the total number of spill trajectories
- probability of exposure to environmental receptors – is determined by ranking the maximum predicted probabilities of exposure for any grid cell within the boundaries of any receptor for each of the 100 trajectories, with the greatest probability from the 100 trajectories being reported for each receptor
- minimum time before hydrocarbon exposure on the sea surface – is determined by ranking the elapsed time before sea surface exposure to a given location/grid cell (above a defined threshold) for each of the 100 spill trajectories, with the minimum time from all spill trajectories being presented
- potential sea surface exposure zones – are calculated for each grid cell and the highest predicted threshold of exposure (i.e. low exposure: 1–10 g/m^2; moderate exposure: 10–25 g/m^2 and high exposure: >25 g/m^2) for any given grid cell based on the assessment of all 100 single spill trajectories
- potential entrained hydrocarbon exposure zones – are calculated for any given grid cell by applying the thresholds of 10 ppb, 100 ppb and 500 ppb
- potential dissolved aromatics exposure zones – calculated for any given grid cell by applying the thresholds of 6 ppb, 50 ppb and 400 ppb
- probability of entrained hydrocarbon or dissolved aromatic exposure – are calculated by dividing the number of spill trajectories passing over that given cell by the total number of spill trajectories above the specified threshold value.

The modelling presents the probability of contact with entrained and dissolved hydrocarbons at depth specific intervals applicable for each of the receptors. For offshore reefs, shoals and banks, the model used the minimum depth of the feature while the surface water layer (0 m–10 m) was used for the Commonwealth marine reserves. The KEFs and commercial fisheries were assessed at different depths as relevant to the maximum depth layer modelled for the scenario. Potential impacts to the KEFs and commercial fisheries were assessed at depths of 40 m–50 m for Scenarios 2, 5 and 6 (vessel collision releasing MDO, HFO and IFO-180), while the 90 m–100 m depth layer was assessed for Scenario 3 (vessel collision releasing Barossa condensate) and Scenario 4 (long-term well blowout).

3.1 Scenario 1: Refuelling incident (10 m³ MDO)

3.1.1 Single trajectory

A spill trajectory during the summer season has been selected to illustrate the change in direction from the general trend (east or north-east). The spill starting at 7 pm 5th December 2010 is presented as an example only. Figure 39 shows the potential sea surface hydrocarbon exposure zones over the 10 day model simulation.

The spill initially drifted north-west of the release location, before travelling south-west. The sea surface adverse exposure zone (moderate and high exposure thresholds) was limited to within 1 km of the release location. There was no entrained or dissolved aromatic hydrocarbon exposure predicted at any threshold; consequently, no subsea images are presented for this scenario.

Figure 40 illustrates the fates and weathering graph for the example spill trajectory. The graph demonstrates that the MDO readily evaporated within the first 24 hours following release and by the end of day 2, approximately 41% (4.1 m³) had undergone evaporation. At the end of the simulation (day 10) approximately 53% (5.3 m³) had evaporated, 42% (4.2 m³) remained on the surface and 5% (0.5 m³) had decayed.

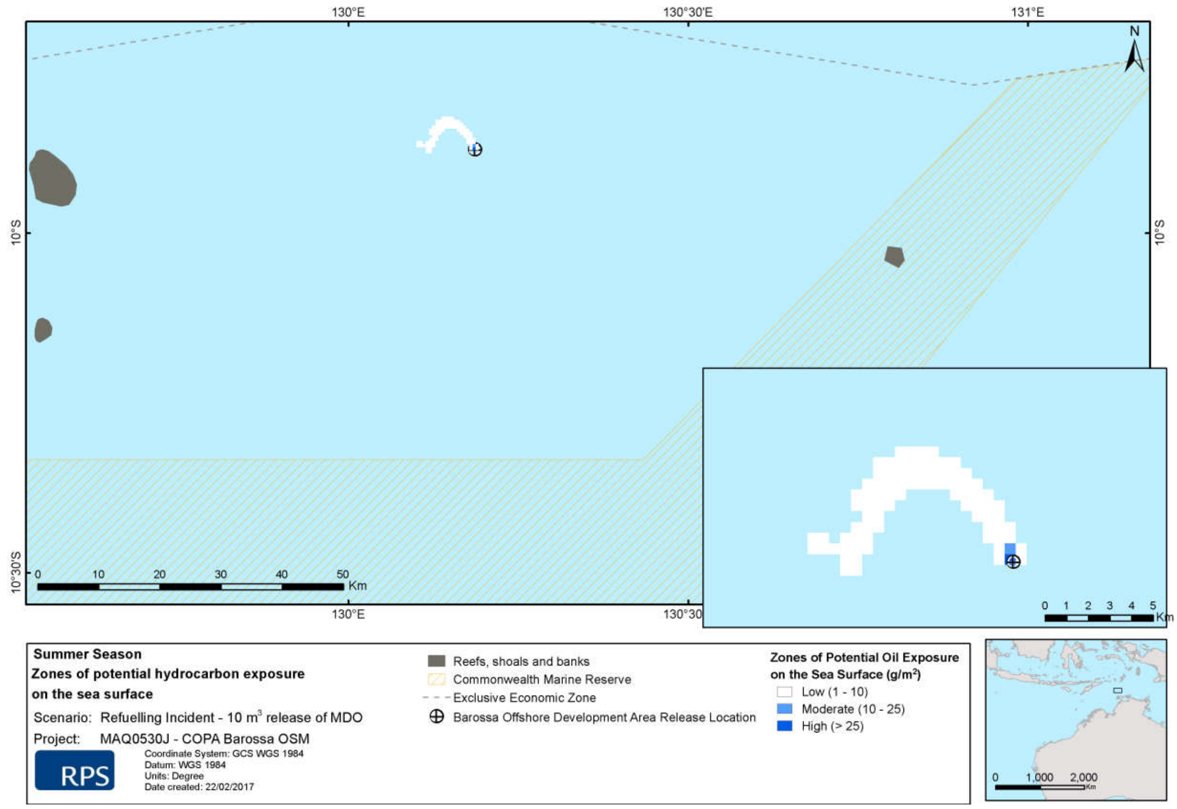


Figure 39 Single spill trajectory outputs showing the potential sea surface exposure zones (10 m³ MDO)

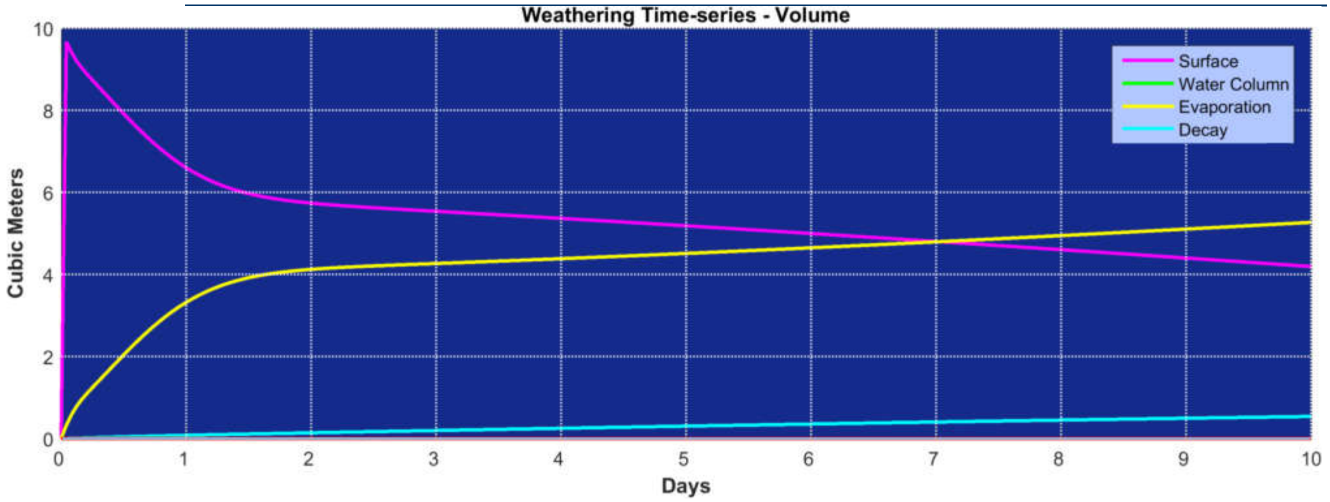


Figure 40 Predicted weathering and fates graph for the example spill trajectory from an instantaneous 10 m^3 surface release of MDO from a refuelling incident (tracked for 10 days)

3.1.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, modelling showed low sea surface exposures towards the east and northeast. Modelling results for the transitional season revealed that spill trajectories travelled west and southwest from the release location. In winter, the spill trajectories were predicted to travel west.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons extending to within 1.4 km, 2.7 km and 3.0 km during summer, transitional and winter conditions, respectively (Table 17).
- contact was predicted by the sea surface adverse exposure zone with the open waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and the Timor Reef Fishery in all seasons as the Barossa offshore development area is located within the bounds of this KEF and Fishery (Table 18).
- no contact was predicted with the sea surface films at shores, reefs or open waters of the CMRs for any threshold in any season. Figure 41 to Figure 43 show the potential exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 44 shows the potential sea surface adverse exposure zone for all seasons.
- no entrained or dissolved aromatic hydrocarbon exposure is predicted at any threshold in any season and therefore, no contact with submerged or in-water receptors is expected.

Table 17 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (10 m^3 MDO)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	26.6	1.4	0.2
	Direction	East-northeast	East-southeast	West-northwest
Transitional	Maximum distance travelled (km) by a spill trajectory	27.5	2.7	0.2
	Direction	West-southwest	West	West-northwest
Winter	Maximum distance travelled (km) by a spill trajectory	26.3	3.0	0.2
	Direction	West	Northwest	West-northwest

Table 18 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (10 m^3 MDO)

Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
Summer conditions (December to February)							
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
KEF	Shelf break slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
KEF	Shelf break slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Winter conditions (April to August)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
KEF	Shelf break slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

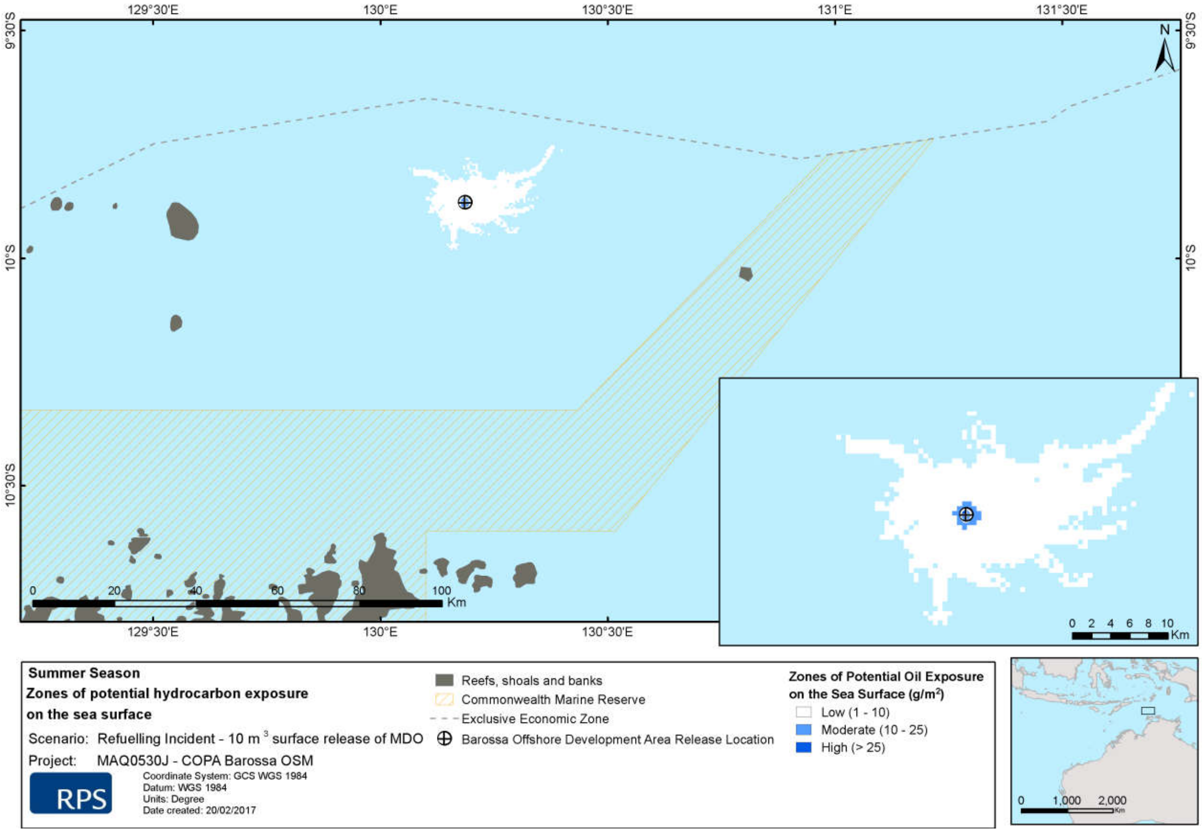


Figure 41 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (10 m^3 MDO)

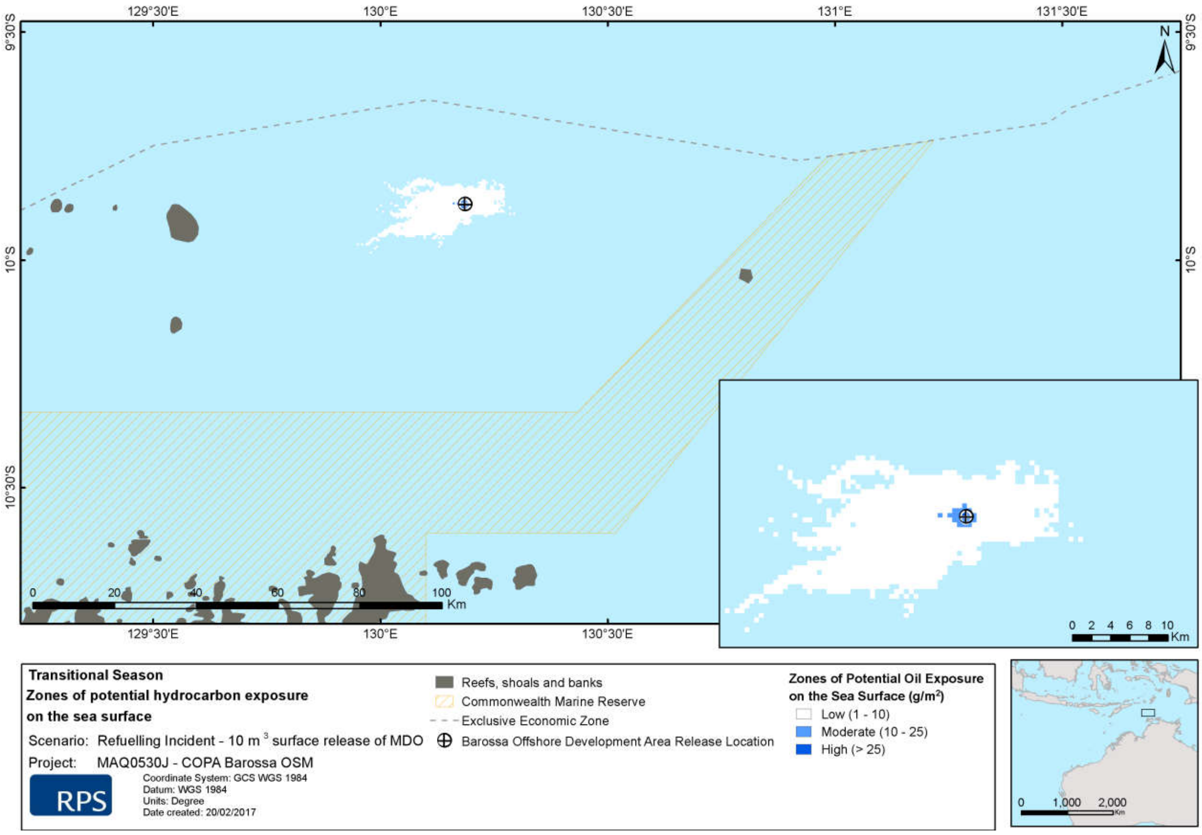


Figure 42 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (10 m^3 MDO)

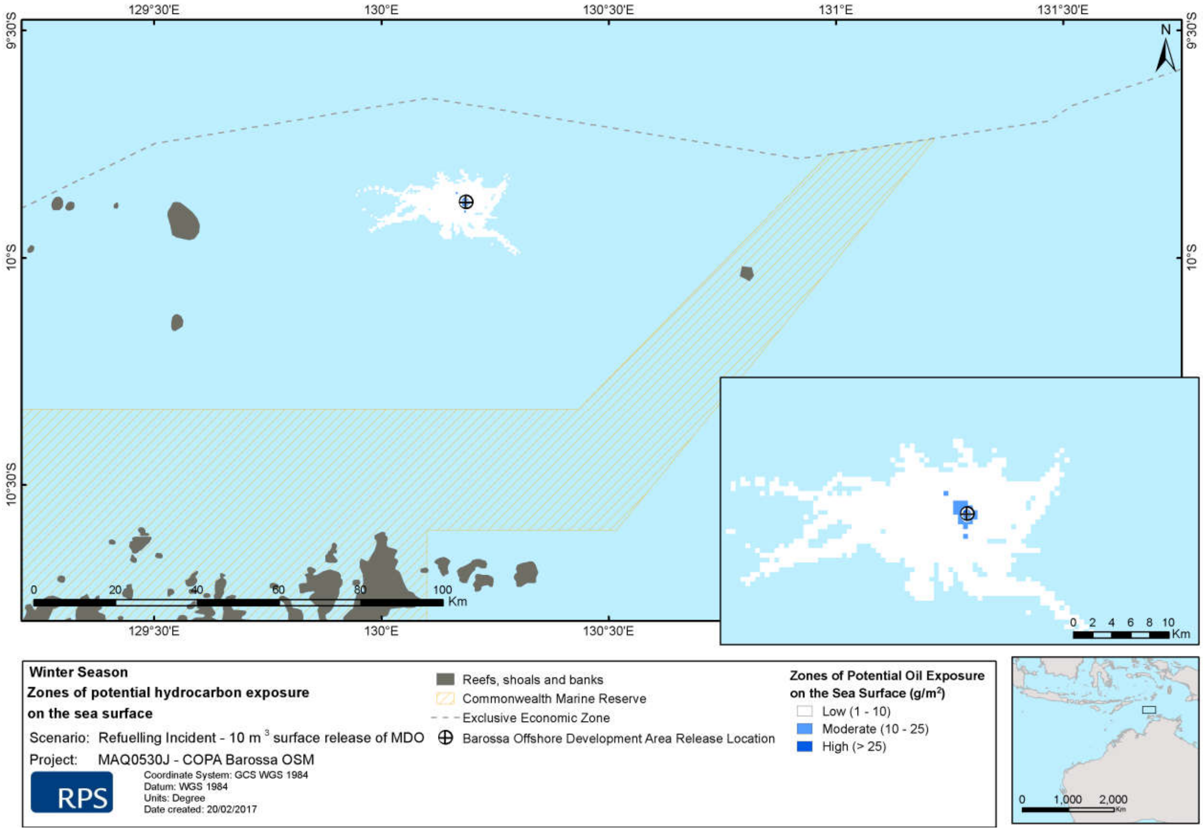


Figure 43 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (10 m^3 MDO)

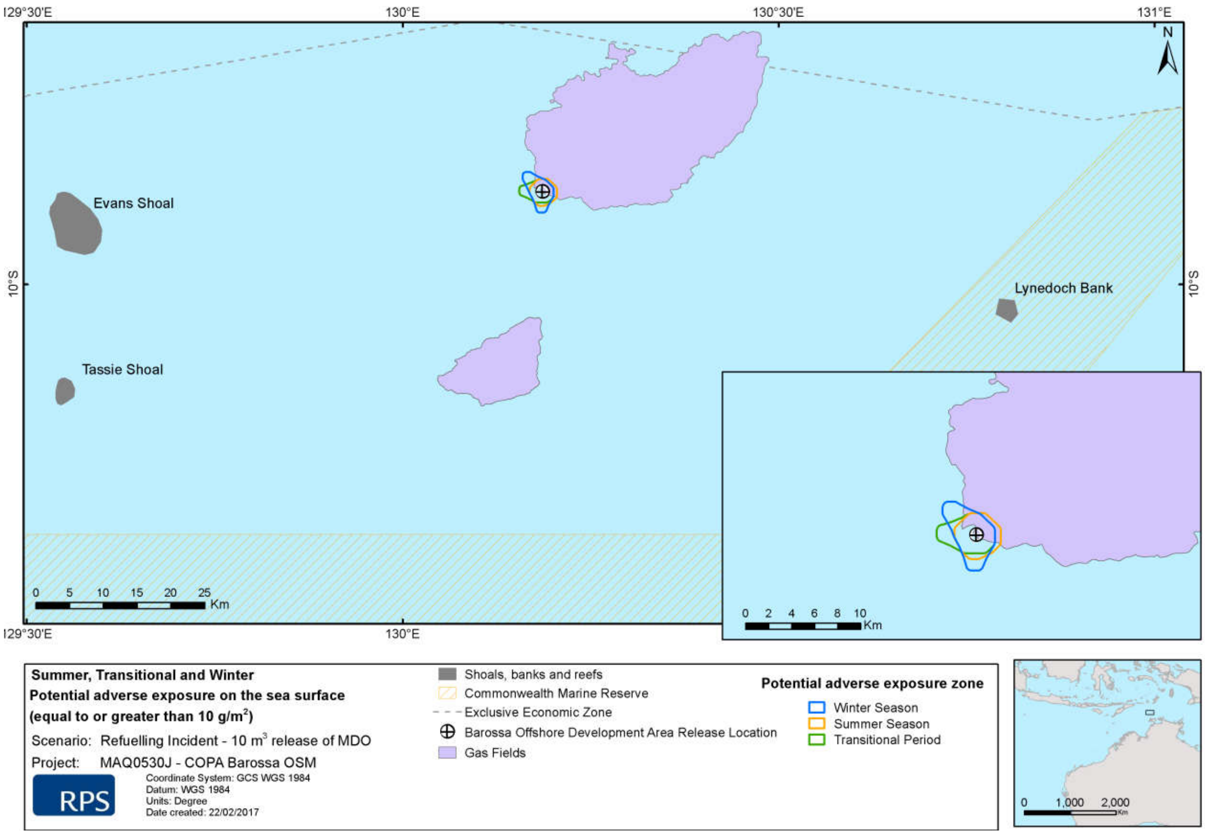


Figure 44 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a refuelling incident releasing MDO (10 m^3)

3.2 Scenario 2: Vessel collision leading to loss of a single FPSO facility (2,975 m^3 MDO)

3.2.1 Single trajectory

Figure 45 shows the predicted sea surface hydrocarbon exposure zones over the entire 40 day model simulation. From the 100 simulations completed, the spill starting at 2 am 8th August 2014 was used as an example trajectory to illustrate the potential exposure toward the south-west by entrained hydrocarbons to adjacent shoals/banks during the winter season. Figure 46 and Figure 47 display the entrained and dissolved aromatic hydrocarbon exposure zones.

The spill generally travelled west from the release location for the entire simulation period. The sea surface adverse exposure zone was observed up to 40 km and 36 km from the release location (moderate and high, respectively). Low, moderate and high entrained hydrocarbon exposure was recorded up to 636 km, 459 km and 172 km, respectively, from the release location. Dissolved aromatic hydrocarbon exposure was predicted up to 106 km from the release location at the low threshold while the adverse exposure zone was limited to within 82 km from the release location.

Figure 48 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that the MDO readily entrained in the water column due to strong winds early in the simulation with approximately 77% (2,278 m^3) of the total spill volume entrained by day 2. The hydrocarbon was observed to remain entrained, undergoing gradual microbial decay, until the end of the simulation. At the end of the simulation (day 40) approximately 23% (972 m^3) had evaporated, 51% (1,540 m^3) remained entrained and 25% (761 m^3) had decayed.

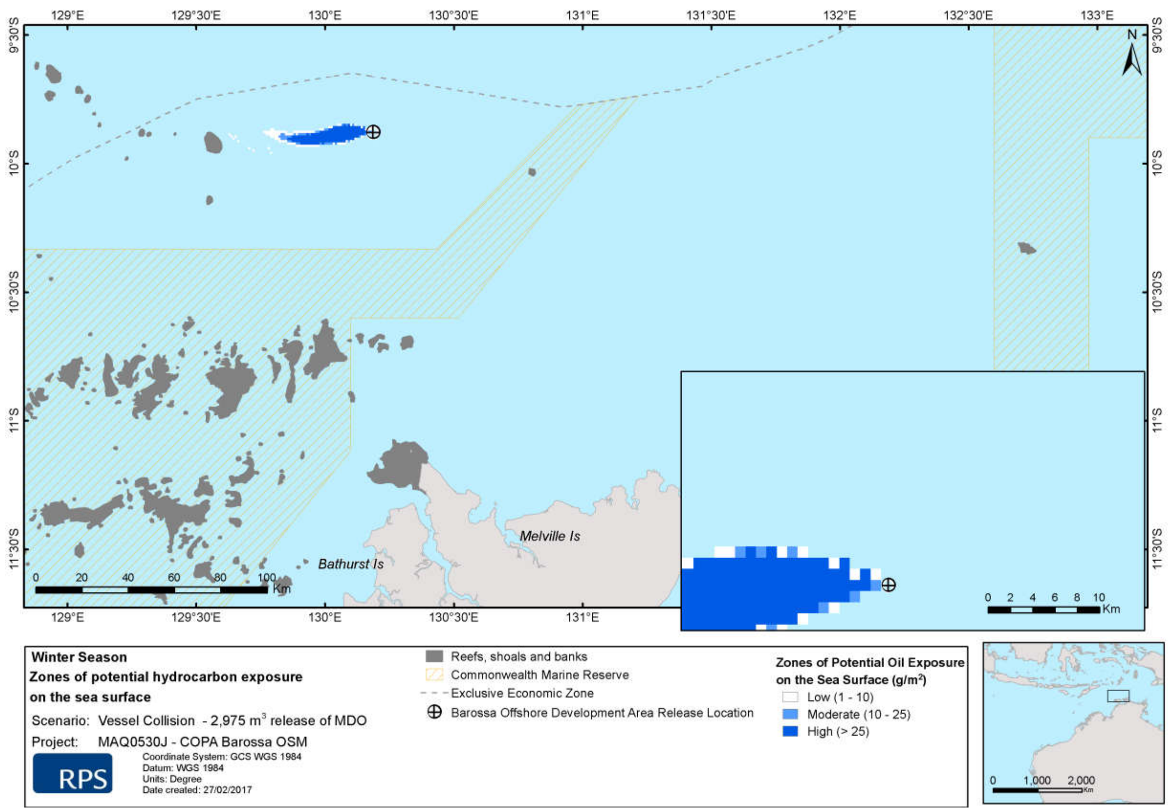


Figure 45 Single spill trajectory outputs showing the potential sea surface exposure zones (2,975 m^3 MDO)

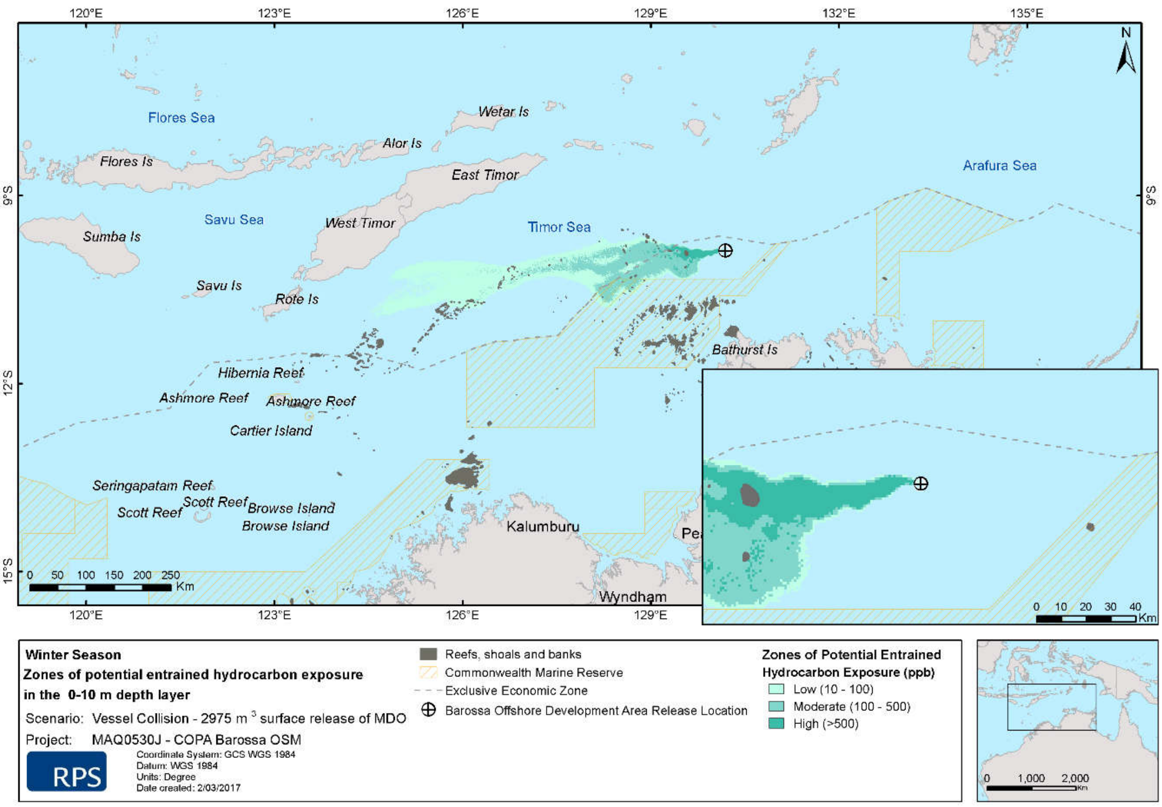


Figure 46 Single spill trajectory outputs showing the potential entrained exposure zones (2,975 m³ MDO)

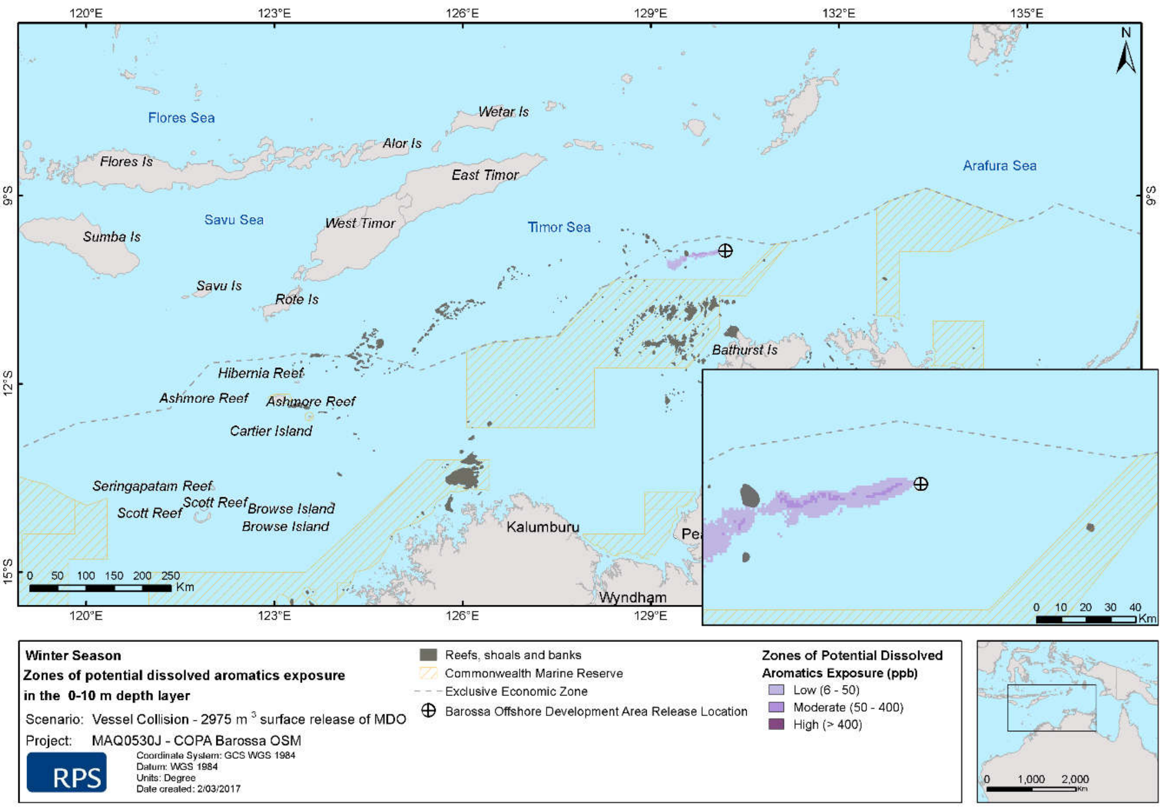


Figure 47 Single spill trajectory outputs showing the potential dissolved aromatic exposure zones (2,975 m³ MDO)

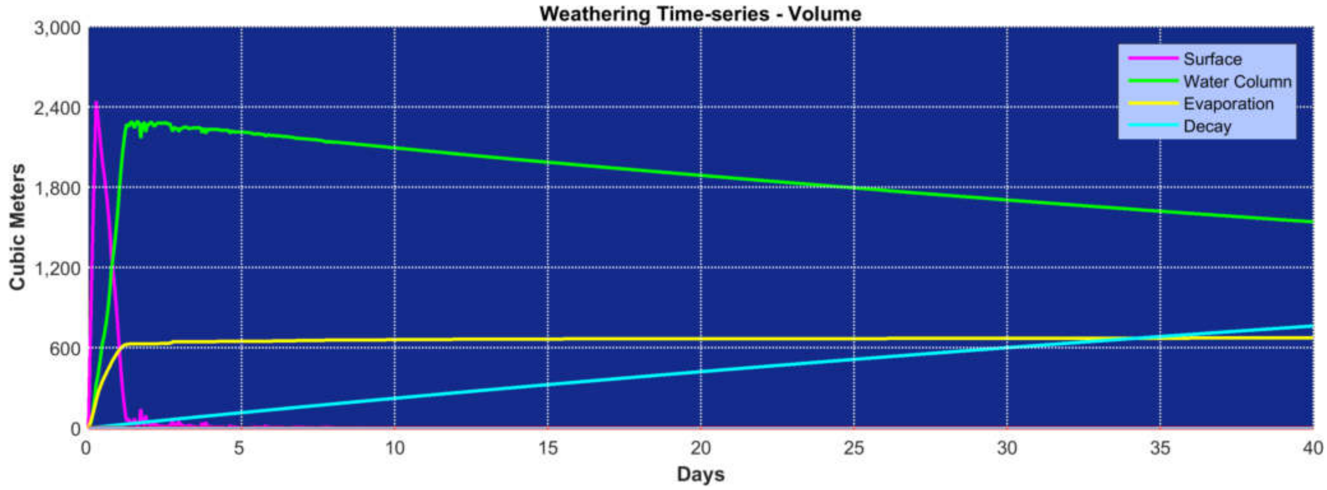


Figure 48 Predicted weathering and fates graph for the example spill trajectory selected from a 2,975 m^3 surface release of MDO from a ship collision and fuel tank rupture (tracked for 40 days)

3.2.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during transitional and winter conditions the MDO initially travelled west of the release location. During the transitional season the MDO was observed to travel greater distances on the sea surface comparative to winter, due to calm to moderate wind speeds which allowed the hydrocarbon on the sea surface to be carried great distances without entraining. During summer the MDO was initially predicted to move east of the release location, but overall movement of sea surface trajectories was variable.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 319 km, 392 km and 124 km of the sea surface exposed during summer, transitional and winter conditions, respectively (Table 19).
- some contact was predicted (1–14% probability) by sea surface films within the adverse exposure zone with the surface waters above a number of submerged shoals/banks (total of 13) KEFs of the carbonate bank and terrace system of Van Diemen Rise and Pinnacles of the Bonaparte Basin, and the open waters of the Oceanic Shoals CMR, depending on the season (Table 20). Figure 49 to Figure 51 show the potential sea surface hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 58 shows the potential sea surface adverse exposure zone for all seasons.
- during summer conditions, the surface waters above Tassie Shoal recorded the highest probability of contact with the sea surface adverse exposure zone of all shoals/banks (2%) while during transitional conditions the waters above Evans Shoal was predicted to have the highest probability of contact with the sea surface adverse exposure zone (14%). During winter conditions, the waters above Evans Shoal, Tassie Shoal, Flinders Shoal and Franklin Shoal were contacted by the sea surface adverse exposure zone (1–2%).
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa offshore development area is located within the bounds of these features (Table 20).
- no residual hydrocarbons were predicted to accumulate on any shoreline in any season to levels that may affect sensitive receptors onshore.
- contact was predicted (1–37% probability) by entrained hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 25), open waters of the Oceanic Shoals, Arafura, Ashmore Reef and Cartier Island CMRs, waters above the KEFs of the shelf break and slope of the Arafura Shelf, carbonate bank and terrace system of Van Diemen Rise, pinnacles of the Bonaparte Basin, carbonate bank and terrace system of Sahul Shelf and tributary canyons of the Arafura Depression, and waters of the Timor

Reef Fishery, depending on the season (Table 21). Figure 52 to Figure 54 shows the potential entrained hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 59 shows the potential entrained hydrocarbon adverse exposure zone for all seasons.

- during summer conditions, Lynedoch Bank recorded the highest probability of contact for submerged shoals with the entrained adverse exposure zone (6%) while during transitional and winter conditions Flinders Shoal was predicted to have the highest probability of contact with entrained the adverse exposure zone (19% and 37% respectively). The open waters of the Oceanic Shoals CMR recorded the highest probability (30%) of contact during summer conditions overall.
- some contact predicted at low probability (1% probability) by entrained hydrocarbons within the adverse exposure zone at Hibernia and Ashmore Reef during transitional conditions only (Table 21)
- some contact predicted at low probability (1–2% probability) by dissolved aromatic hydrocarbons within the adverse exposure zone for 10 submerged shoals/banks, open waters of the Oceanic Shoals CMR, waters above the KEFs of the shelf break and slope of the Arafura Shelf and carbonate bank and terrace system of Van Diemen Rise, and waters of the Timor Reef Fishery, depending on the season (Table 22). Figure 55 to Figure 57 shows the potential dissolved aromatic hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 60 shows the potential dissolved aromatic hydrocarbon adverse exposure zone for all seasons.
- no contact with the adverse exposure zone for sea surface or sub-surface hydrocarbons was predicted with the NT/WA coastline or adjacent islands (Table 20 to Table 22).

Table 19 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (2,975 m^3 MDO)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	366.9	318.5	153.2
	Direction	West	West	West-southwest
Transitional	Maximum distance travelled (km) by a spill trajectory	679.9	391.7	367.1
	Direction	West-southwest	West-southwest	West
Winter	Maximum distance travelled (km) by a spill trajectory	590.9	124.2	91.1
	Direction	West	West-southwest	West-southwest

Table 20 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (2,975 m^3 MDO)

Summer conditions (December to February)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	1	-	-	17.5	-	-
	Martin Shoal	1	1	-	10.4	12.4	-
	Sunrise Bank	1	-	-	16.4	-	-
	Troubadour Shoals	1	-	-	9.3	-	-
	Flinders Shoal	-	-	-	-	-	-
	Evans Shoal	6	1	-	3.4	19.0	-
	Tassie Shoal	7	2	-	6.2	6.2	-
	Franklin Shoal	1	-	-	10.9	-	-
	Blackwood Shoal	2	-	-	10.8	-	-
	Lynedoch Bank	4	-	-	4.0	-	-
	Margaret Harries Bank	3	1	-	9.5	19.8	-
	Bellona Bank	1	-	-	34.0	-	-
	Echo Shoals	1	-	-	34.3	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	2	1	-	12.6	14.2	-
	Sahul Bank	-	-	-	-	-	-
Emergent	Indonesia	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	30	12	8	2.8	4.5	6.4
KEF	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	18	16	9	3.0	3.4	3.5
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Transitional conditions (March and September to November)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	16	4	1	5.7	6.2	10.5
	Loxton Shoal	15	4	-	5.4	5.8	-
	Martin Shoal	9	2	-	4.9	5.1	-
	Sunrise Bank	9	3	-	11.5	22.9	-
	Troubadour Shoals	16	6	-	7.6	7.9	-
	Flinders Shoal	18	9	3	3.9	4.1	4.3
	Evans Shoal	28	14	6	2.3	2.4	2.5
	Tassie Shoal	6	2	-	4.2	7.5	-
	Franklin Shoal	16	9	3	3.8	3.9	4.3
	Blackwood Shoal	14	8	1	3.4	3.4	5.5
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	13	3	-	7.4	10.3	-
	Bellona Bank	5	1	1	18.2	18.4	18.8
	Echo Shoals	8	-	-	18.4	-	-
	Big Bank Shoals	1	-	-	21.3	-	-
	Karmt Shoal	1	-	-	22.0	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Sahul Bank	1	-	-	33.7	-	-
Emergent	Indonesia	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	9	5	3	3.0	3.2	5.6
KEF	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	27	15	6	2.7	2.8	2.8
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Winter conditions (April to August)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	-	-	-	-	-	-
	Martin Shoal	1	-	-	3.75	-	-
	Sunrise Bank	-	-	-	-	-	
	Troubadour Shoals	2	-	-	3.08	-	-
	Flinders Shoal	2	1	-	1.67	1.7	-
	Evans Shoal	5	2	-	3.79	3.8	
	Tassie Shoal	3	2	-	3.02	3.1	
	Franklin Shoal	2	1	-	2.46	2.5	-
	Blackwood Shoal	3	-	-	8	15.0	-
	Lynedoch Bank	1	-	-	8.3	-	-
	Margaret Harries Bank	2	1	-	12.6	15.1	-
	Bellona Bank	1	-	-	13.33	-	-
	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	1	-	-	4.81	-	-
	Karmt Shoal	1	-	-	15.75	-	-
	Cootamundra Shoal	1	-	-	17.25	-	-
	Sahul Bank	1	-	-	19.22	-	-
Emergent	Indonesia	1	-	-	20.63	-	-
CMR	Oceanic Shoals CMR	2	1	-	21.06	22.0	-
KEF	Shelf break and slope of the Arafura Shelf	100	100	100	22.04	26.0	35.33
	Carbonate bank and terrace system of Van Diemen Rise	16	8	4	28.31	31.0	34.8
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	33.67	-	-

Table 21 Probability and minimum time before entrained hydrocarbon exposure for receptors assessed (2,975 m^3 MDO)

Summer conditions (December to February)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	3	1	-	10.4	36.7	-
	Loxton Shoal	3	1	-	9.5	12.1	-
	Martin Shoal	2	2	-	9.8	18.8	-
	Sunrise Bank	-	-	-	-	-	-
	Flinders Shoal	7	1	-	10.8	35.7	-
	Evans Shoal	10	1	-	12.5	19.0	-
	Tassie Shoal	12	5	-	9.4	12.7	-
	Franklin Shoal	4	1	-	10.8	35.7	-
	Blackwood Shoal	7	1	-	10.7	19.1	-
	Lynedoch Bank	23	6	1	2.7	2.9	3.0
	Margaret Harries Bank	5	1	-	18.0	19.8	-
	Bellona Bank	1	-	-	35.3	-	-
	Echo Shoals	1	-	-	35.2	-	-
	Money Shoal	13	3	-	20.6	22.4	-
	Troubadour Shoals	1	1	-	29.5	31.5	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	7	1	-	14.1	15.2	-
	Calder Shoal	6	1	-	14.0	18.5	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-

	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	2	1	-	29.1	31.4	-
	East Timor	1	-	-	37.0	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	33	13	2	15.1	18.1	21.7
	Oceanic Shoals CMR	47	30	11	2.1	2.2	2.5
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	19	4	1	16.9	19.1	25.6
	Shelf break and slope of the Arafura Shelf	22	12	2	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	12	2	1	4.7	10.8	12.7
	Pinnacles of the Bonaparte Basin	1	-	-	20.6	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	25	12	2	0.04	0.04	0.04

Transitional conditions (March and September to November)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	21	6	-	7.8	8.0	-
	Loxton Shoal	25	5	-	5.8	7.2	
	Martin Shoal	20	2	-	5.8	6.9	
	Sunrise Bank	17	-	-	8.4	-	
	Flinders Shoal	36	19	-	3.2	3.9	
	Evans Shoal	30	9	-	1.6	1.8	
	Tassie Shoal	17	3	-	2.2	2.3	
	Franklin Shoal	28	3	-	3.2	4.4	

	Blackwood Shoal	27	1	-	2.8	3.3	-
	Lynedoch Bank	8	4	1	3.4	4.3	6.7
	Margaret Harries Bank	21	3	-	7.5	8.0	
	Bellona Bank	20	-	-	13.2	16.4	
	Echo Shoals	25	-	-	16.3	18.0	
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	28	5	-	7.0	7.8	-
	Big Bank Shoals	16	-	-	19.7	-	-
	Karmt Shoal	18	-	-	19.8	-	-
	Cootamundra Shoal	1	1	-	24.9	27.8	-
	Calder Shoal	1	1	-	31.9	35.7	-
	Sahul Bank	21	-	-	20.8	-	-
	Dillon Shoal	14	1	-	20.5	24.5	-
	Barton Shoal	7	-	-	22.8	-	-
	Fantome Shoal	5	1	-	32.9	34.9	-
	Mangola Shoal	3	1	-	24.9	28.9	-
	Jabiru Shoals	4	-	-	25.0	-	-
	Pee Shoal	3	-	-	27.3	-	-
	Vee Shoal	2	-	-	33.9		-
	Johnson Bank	5	-	-	35.5	-	-
	Woodbine Bank	3	-	-	37.2	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	5	2	1	17.1	17.4	21.3
	East Timor	8	1	-	26.9	35.0	-
	Hibernia Reef	8	1	-	33.7	33.9	-
	Ashmore Reef	5	1	-	35.2	36.7	-
	Cartier Island	1	-	-	37.9	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	19	9	4	2.9	3.1	5.7
	Ashmore Reef CMR	6	-	-	35.0	-	-
	Cartier Island CMR	3	-	-	37.8	-	-

KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	14	4	2	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	18	6	1	1.8	1.9	2.0
	Pinnacles of the Bonaparte Basin	9	2	-	13.3	14.1	
	Carbonate bank and terrace system of Sahul Shelf	3	-	-	24.9	-	-
Fishery	Timor Reef Fishery (NT Managed)	18	3	2	0.04	3.0	0.04
Winter conditions (April to August)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	41	11	1	4.7	4.8	7.1
	Loxton Shoal	42	14	-	4.3	4.4	
	Martin Shoal	39	11	2	3.8	3.8	3.8
	Sunrise Bank	27	4	-	7.3	7.9	
	Flinders Shoal	63	37	13	3.1	3.2	3.2
	Evans Shoal	59	31	5	1.7	1.7	2.1
	Tassie Shoal	35	9	-	3.8	3.8	
	Franklin Shoal	52	28	-	3.0	3.1	
	Blackwood Shoal	54	23	1	2.5	2.5	2.6
	Lynedoch Bank	11	1	-	8.0	15.0	
	Margaret Harries Bank	24	8	3	8.3	9.3	11.3
	Bellona Bank	23	4	-	12.6	15.1	
	Echo Shoals	26	7	1	13.3	15.9	19.9
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	44	17	2	4.8	5.3	7.5
	Big Bank Shoals	27	8	1	15.8	16.0	19.9
	Karmt Shoal	29	7	1	17.3	19.8	24.5
	Cootamundra Shoal	1	1	-	19.2	20.4	-
	Calder Shoal	1	1	-	20.6	21.5	-
	Sahul Bank	28	11	1	21.1	22.0	36.0
	Dillon Shoal	23	5	1	22.0	26.0	35.3

	Barton Shoal	10	3	-	28.3	31.0	
	Fantome Shoal	2	-	-	35.4	-	-
	Mangola Shoal	5	1	-	33.7	35.6	-
	Jabiru Shoals	6	1	-	31.0	37.7	-
	Pee Shoal	7	1	-	31.1	37.6	-
	Vee Shoal	3	-	-	36.1	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	9	4	1	19.4	27.3	38.2
	East Timor	3	1	-	21.9	24.1	-
	Hibernia Reef	1	-	-	38.0	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	23	13	6	4.8	4.8	5.7
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	23	6	2	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	22	5	2	1.7	1.8	2.0
	Pinnacles of the Bonaparte Basin	8	1	-	13.6	14.3	
	Carbonate bank and terrace system of Sahul Shelf	3	1	-	26.3	28.6	
Fishery	Timor Reef Fishery (NT Managed)	24	3	2	0.04	0.04	0.04

Table 22 Probability and minimum time before dissolved aromatic hydrocarbon exposure for receptors assessed (2,975 m³ MDO)

Summer conditions (December to February)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	-	-	-	-	-	-
	Martin Shoal	-	-	-	-	-	-
	Sunrise Bank	-	-	-	-	-	-
	Flinders Shoal	-	-	-	-	-	-
	Evans Shoal	-	-	-		-	-
	Tassie Shoal	-	-	-	-	-	-
	Franklin Shoal	-	-	-	-	-	-
	Blackwood Shoal	-	-	-	-	-	-
	Lynedoch Bank	1	-	-	15.5	-	-
	Margaret Harries Bank	1	-	-	29.8	-	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	1	-	-	32.2	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-

	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-		-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	2	-	-	18.2	-	-
	Oceanic Shoals CMR	7	1	-	3.2	3.7	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	3	-	-	30.0	-	-
	Shelf break and slope of the Arafura Shelf	14	2	-	0.04	0.09	-
	Carbonate bank and terrace system of Van Diemen Rise	1	-	-	9.0	-	-
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	14	2	-	0.04	0.09	-

Transitional conditions (March and September to November)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	2	-	-	18.2	-	-
	Loxton Shoal	3	-	-	7.8	-	-
	Martin Shoal	-	-	-		-	-
	Sunrise Bank	1	-	-	21.1	-	-
	Flinders Shoal	2	-	-	4.3	-	-
	Evans Shoal	4	1	-	2.8	3.0	-
	Tassie Shoal	5	1	-	2.3	4.8	-
	Franklin Shoal	2	-	-	4.4	-	-
	Blackwood Shoal	1	-	-	10.3	-	-

	Lynedoch Bank	2	-	-	7.1	-	-
	Margaret Harries Bank	1	-	-	10.2	-	-
	Bellona Bank	-	-	-		-	-
	Echo Shoals	-	-	-		-	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	4	1	-	9.3	12.3	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	21.3	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	3	1	-	6.2	7.0	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-

	Shelf break and slope of the Arafura Shelf	11	2	-	0.04	0.06	-
	Carbonate bank and terrace system of Van Diemen Rise	7	-	-	2.3	-	-
	Pinnacles of the Bonaparte Basin	3	-	-	14.3	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	11	2	-	0.04	0.06	-
Winter conditions (April to August)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	7	1	-	5.0	6.3	-
	Loxton Shoal	7	1	-	4.5	7.3	-
	Martin Shoal	5	1	-	4.1	4.2	-
	Sunrise Bank	2	-	-	9.5	-	-
	Flinders Shoal	10	1	-	3.4	4.8	-
	Evans Shoal	18	2	-	2.5	2.6	-
	Tassie Shoal	5	1	-	5.6	7.9	-
	Franklin Shoal	14	1	-	3.4	3.8	-
	Blackwood Shoal	15	1	-	3.3	5.6	-
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	2	1	-	11.4	12.4	-
	Bellona Bank	2	-	-	23.6	-	-
	Echo Shoals	3	-	-	16.7	-	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	8	-	-	7.2	-	-
	Big Bank Shoals	1	-	-	22.7	-	-
	Karmt Shoal	3	-	-	21.0	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	2	-	-	24.9	-	-
	Dillon Shoal	1	-	-	31.0	-	-
	Barton Shoal	-	-	-	-	-	-

	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	30.9	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	3	1	-	6.6	8.7	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	18	4	-	0.04	0.04	-
	Carbonate bank and terrace system of Van Diemen Rise	8	1	-	2.2	2.2	-
	Pinnacles of the Bonaparte Basin	2	-	-	21.7	-	-
	Carbonate bank and terrace system of Sahul Shelf	2	-	-	28.3	-	-
Fishery	Timor Reef Fishery (NT Managed)	18	4	-	0.04	0.04	-

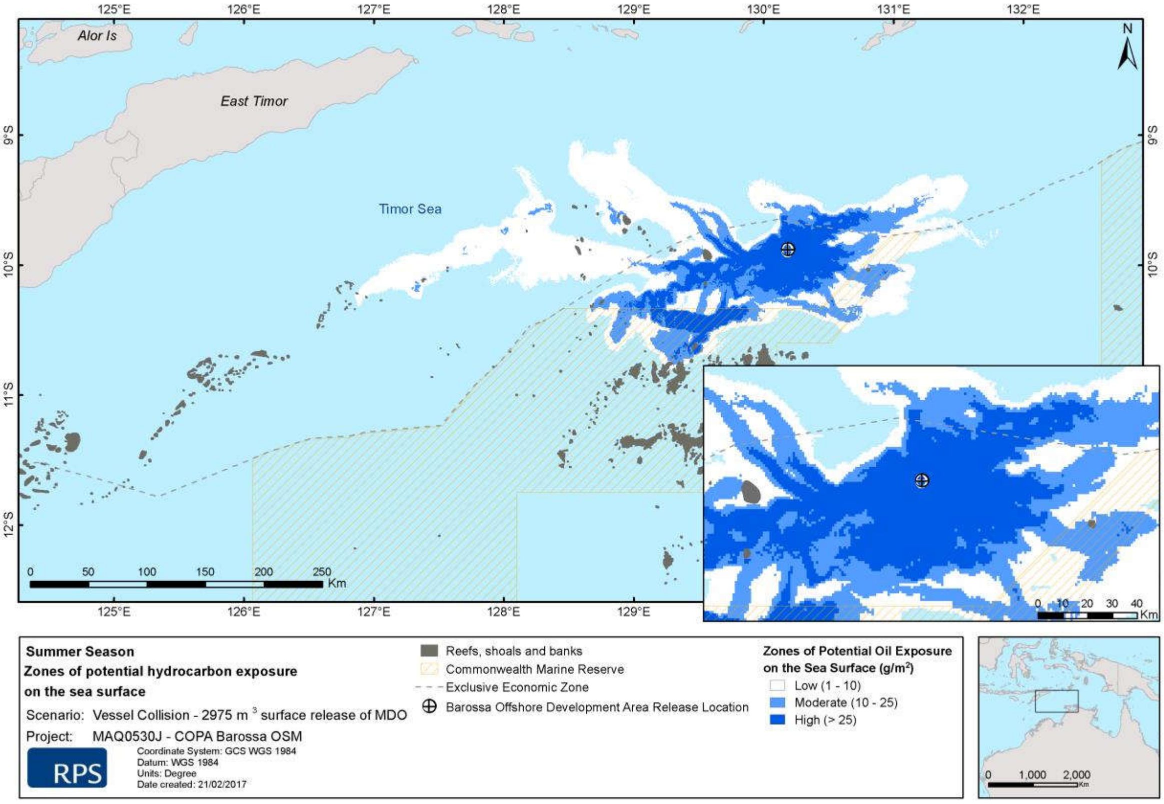


Figure 49 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (2,975 m³ MDO)

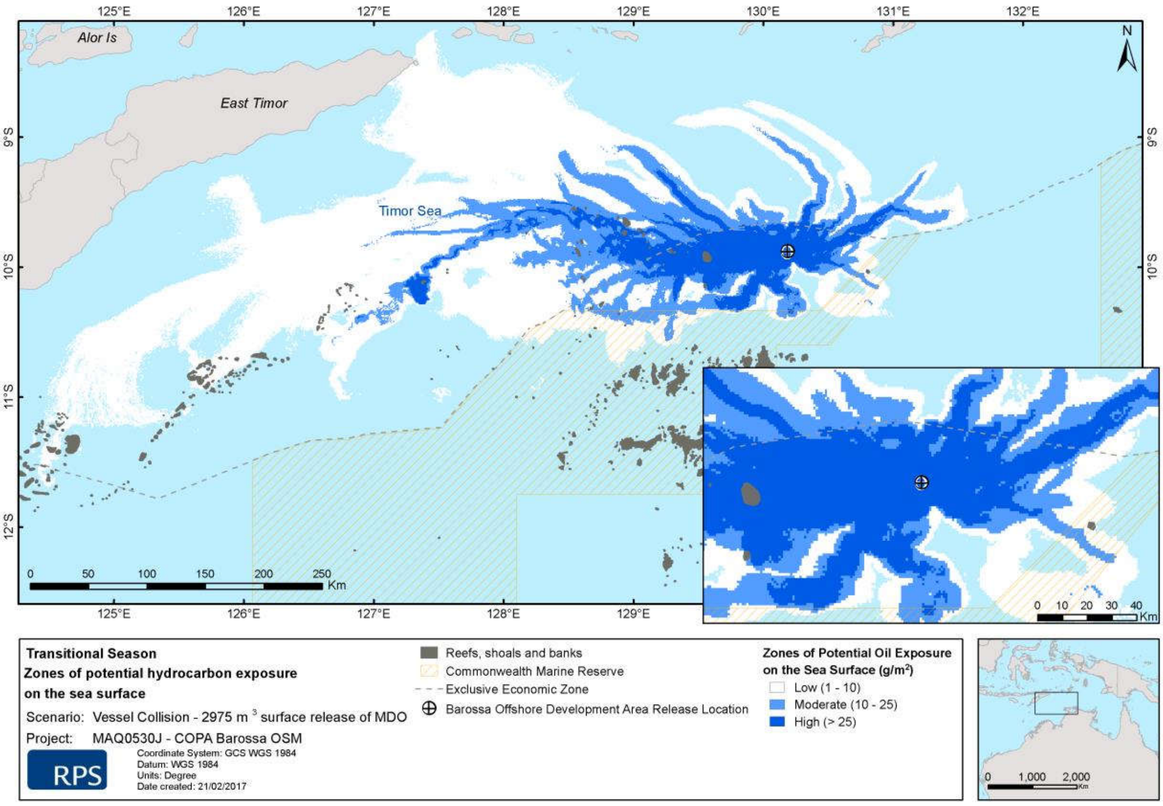


Figure 50 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (2,975 m³ MDO)

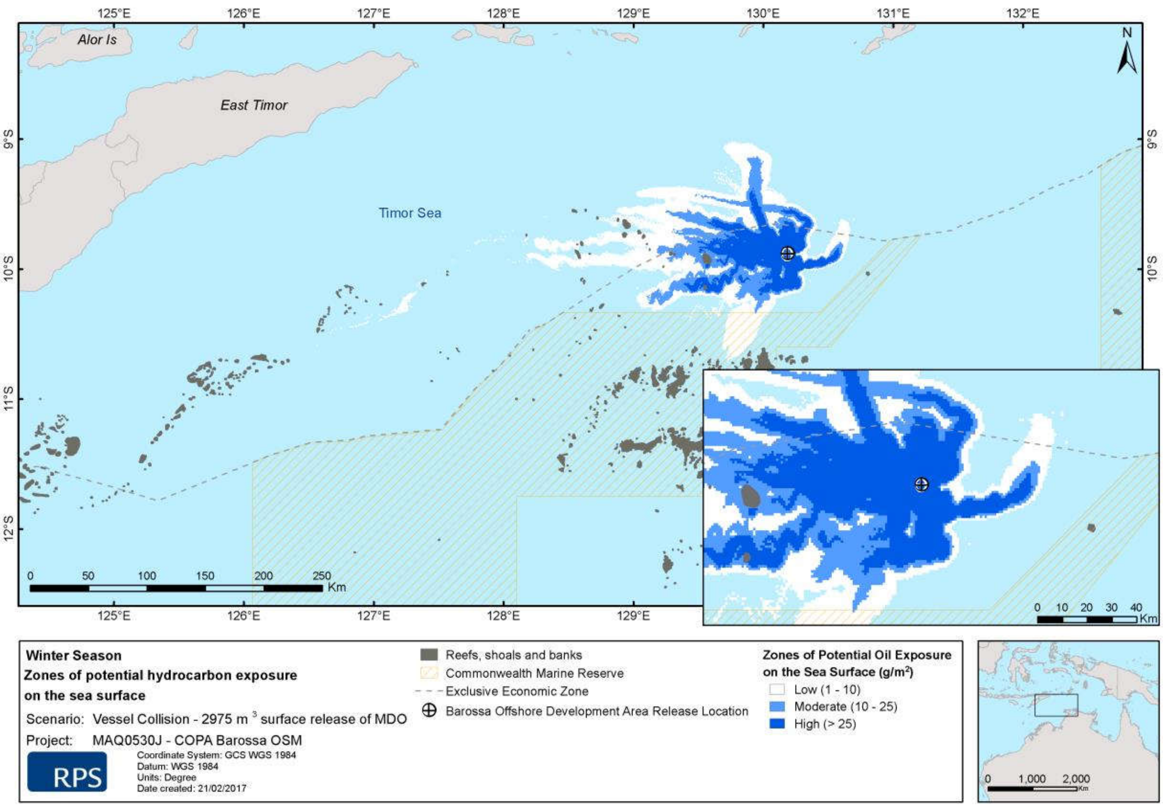


Figure 51 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (2,975 m^3 MDO)

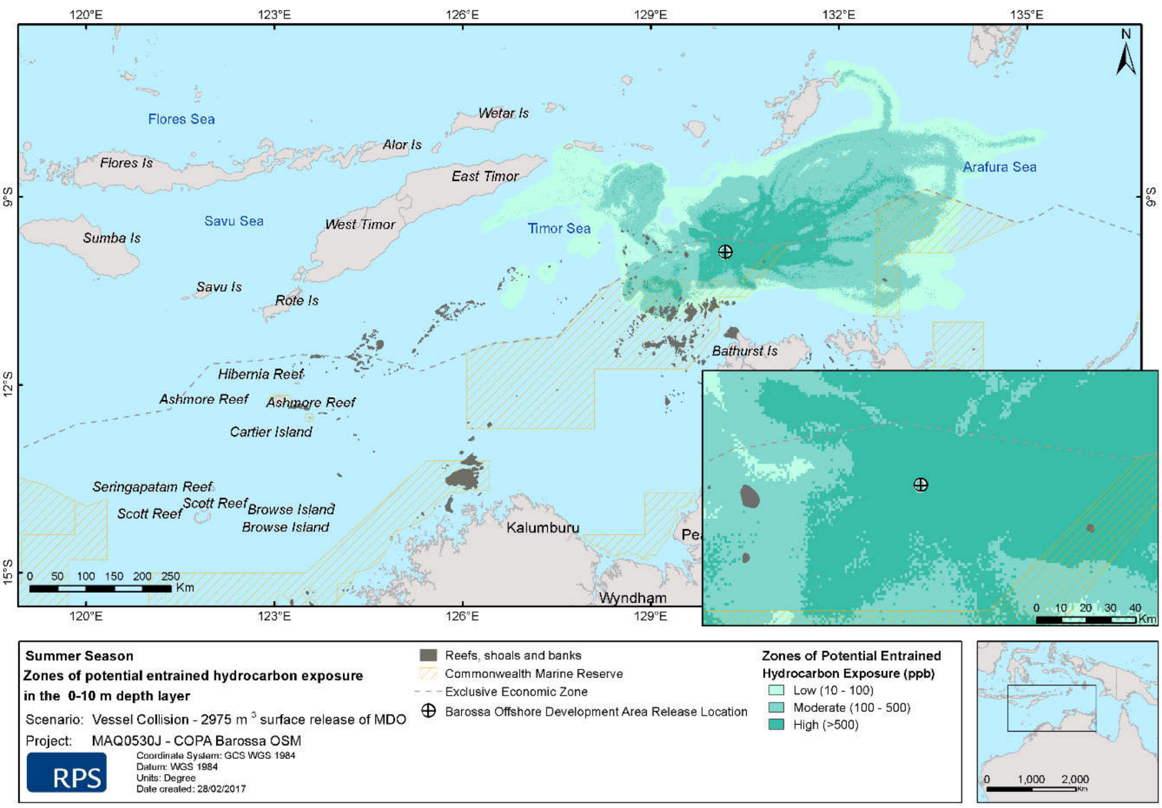


Figure 52 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (2,975 m^3 MDO)

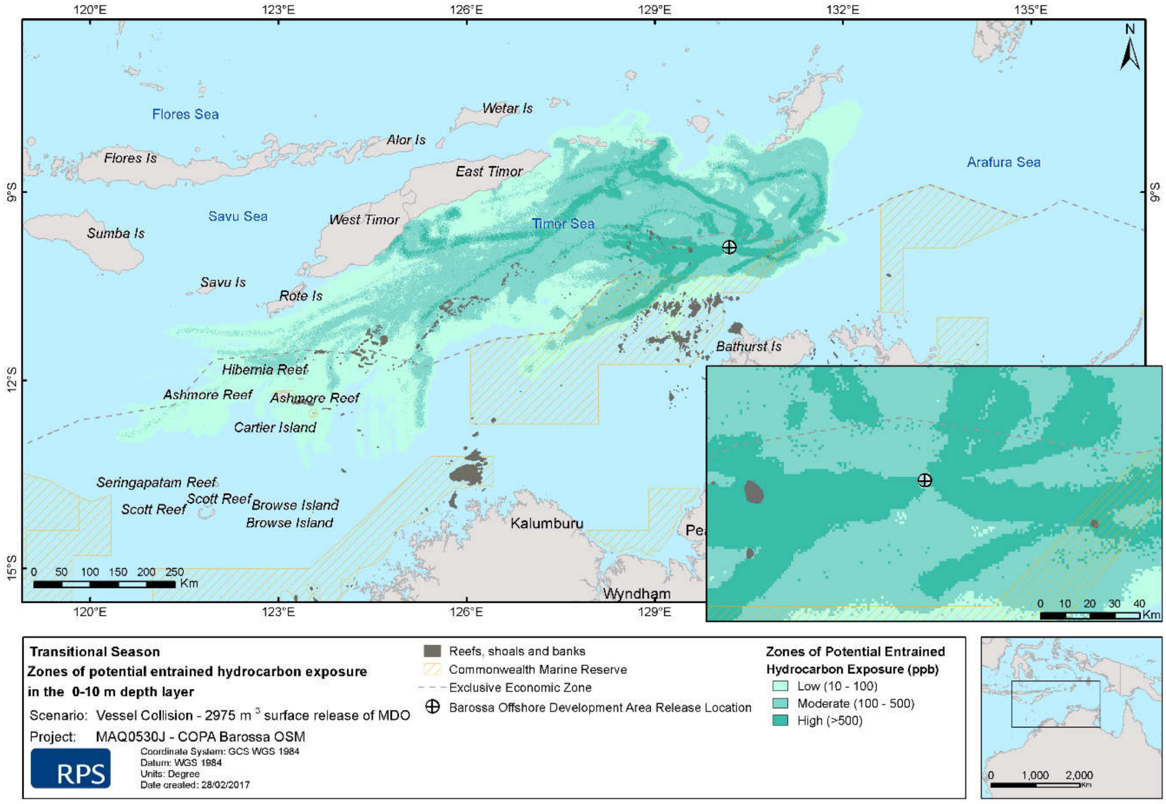


Figure 53 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (2,975 m^3 MDO)

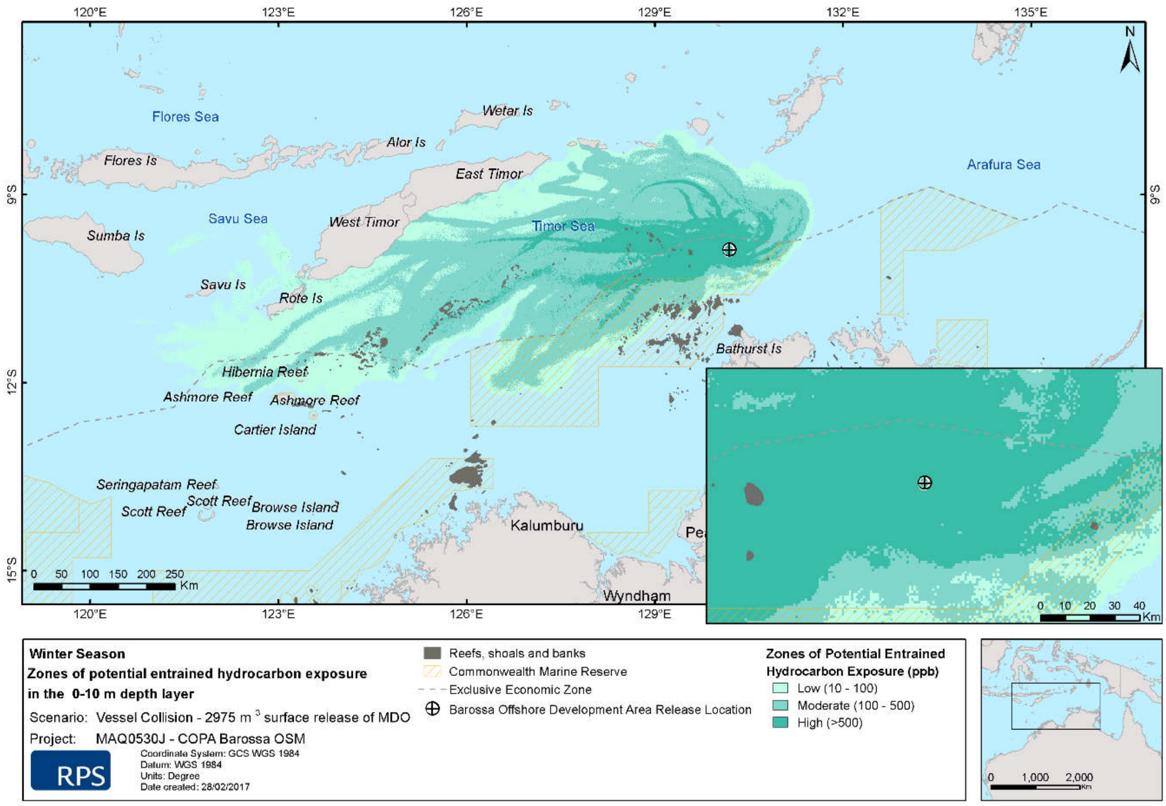


Figure 54 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (2,975 m^3 MDO)

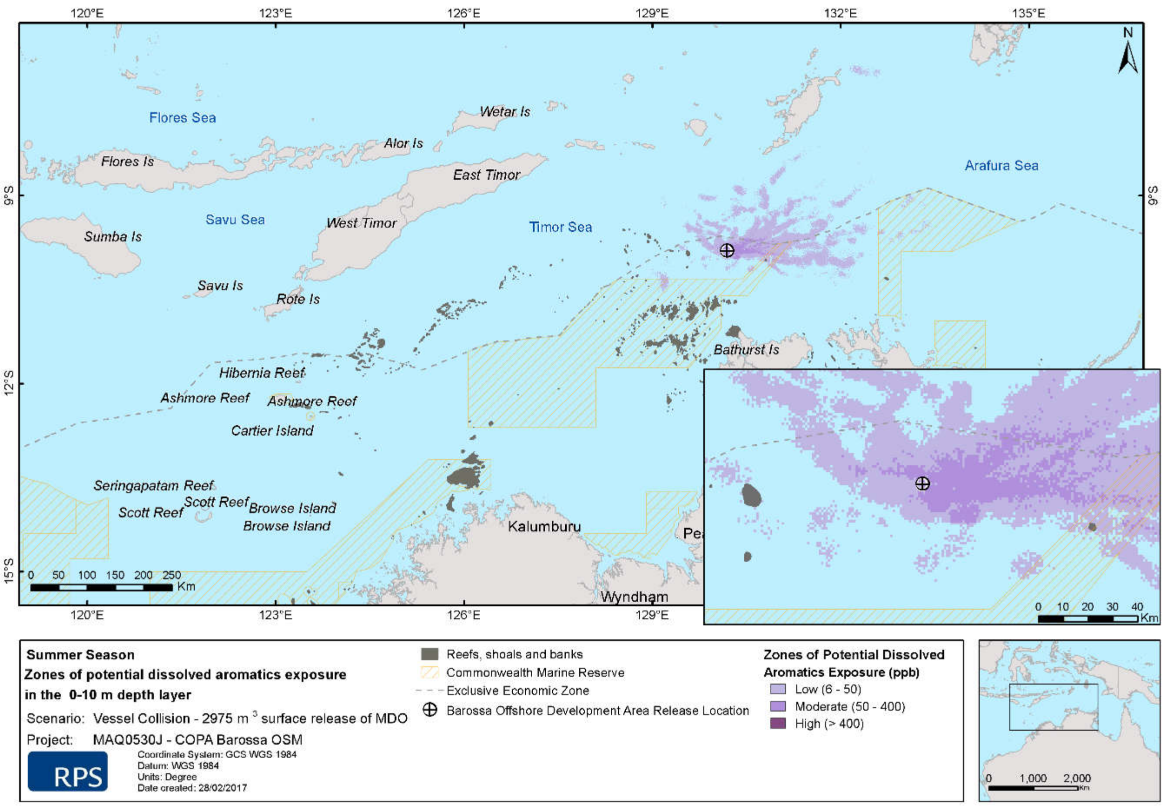


Figure 55 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (2,975 m³ MDO)

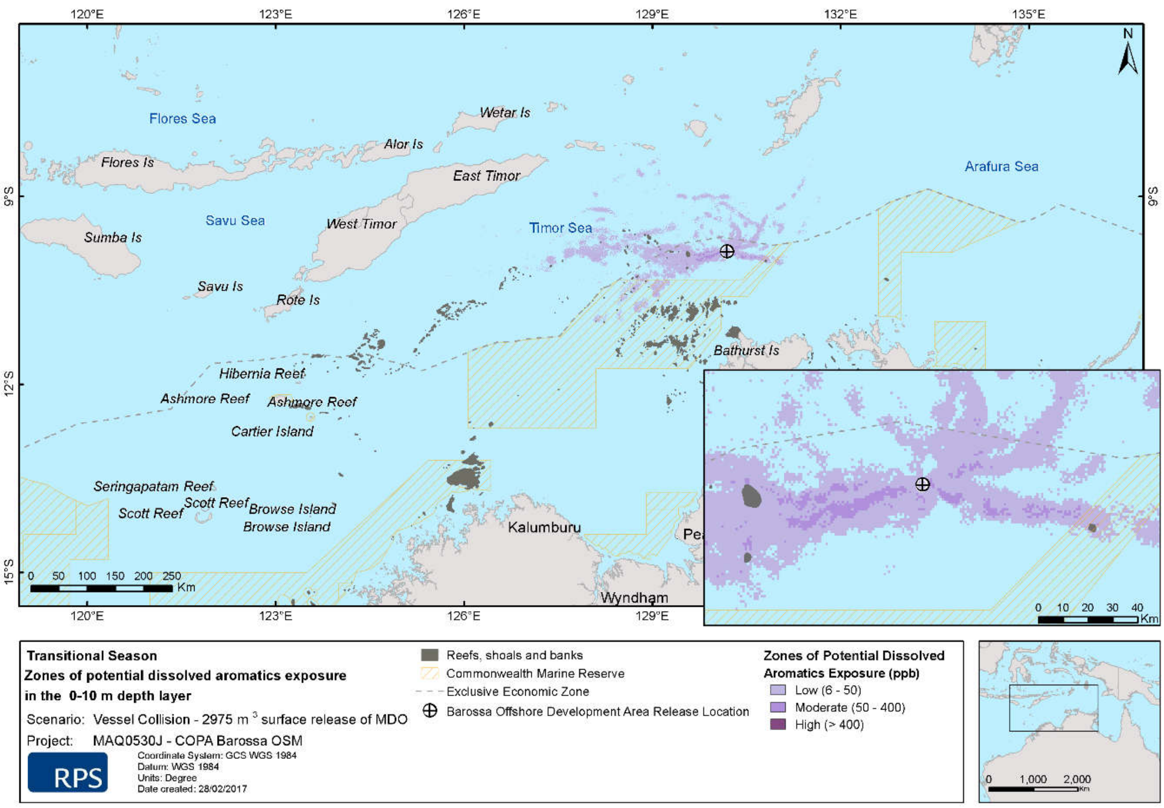


Figure 56 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (2,975 m³ MDO)

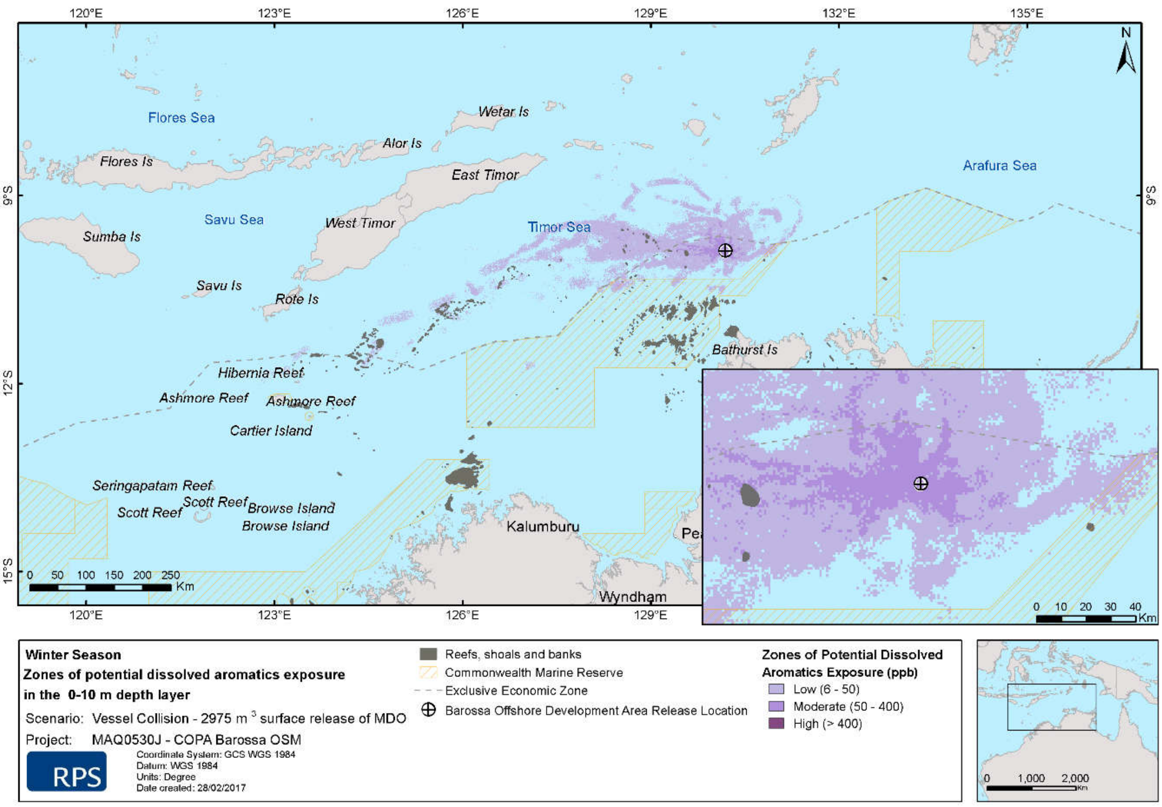


Figure 57 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (2,975 m^3 MDO)

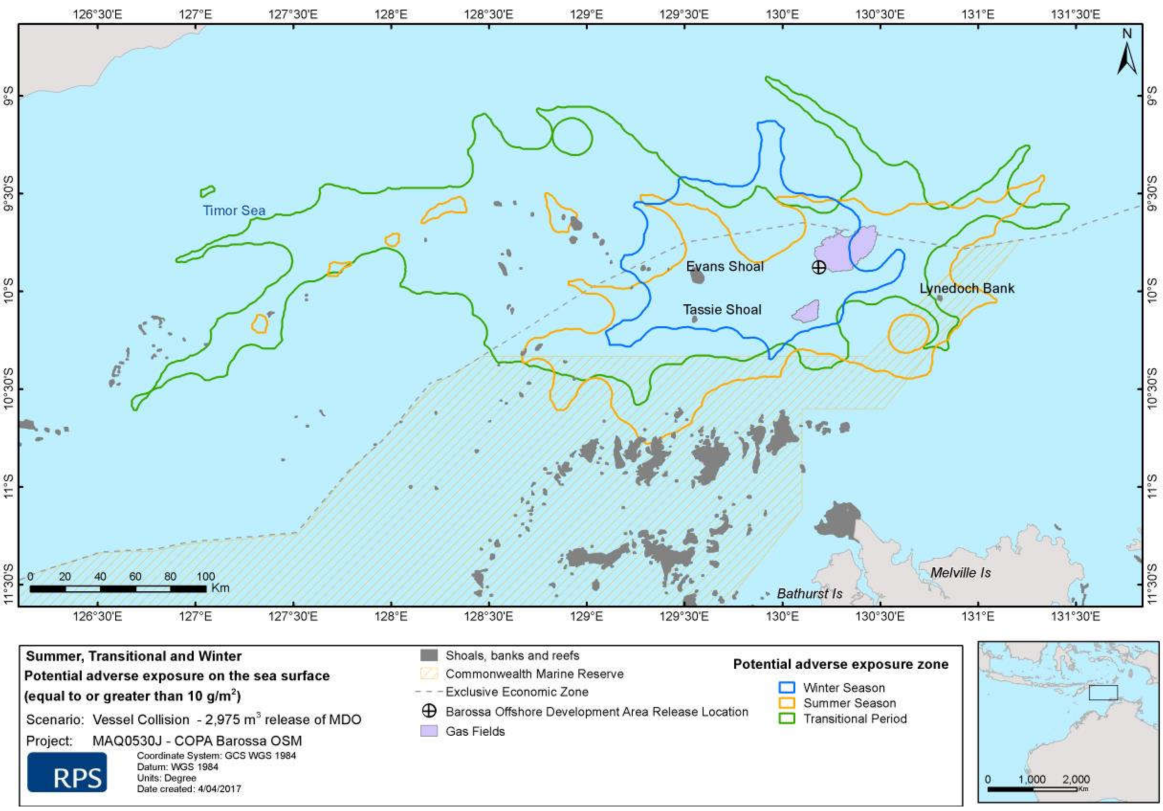


Figure 58 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a vessel collision releasing MDO (2,975 m^3)

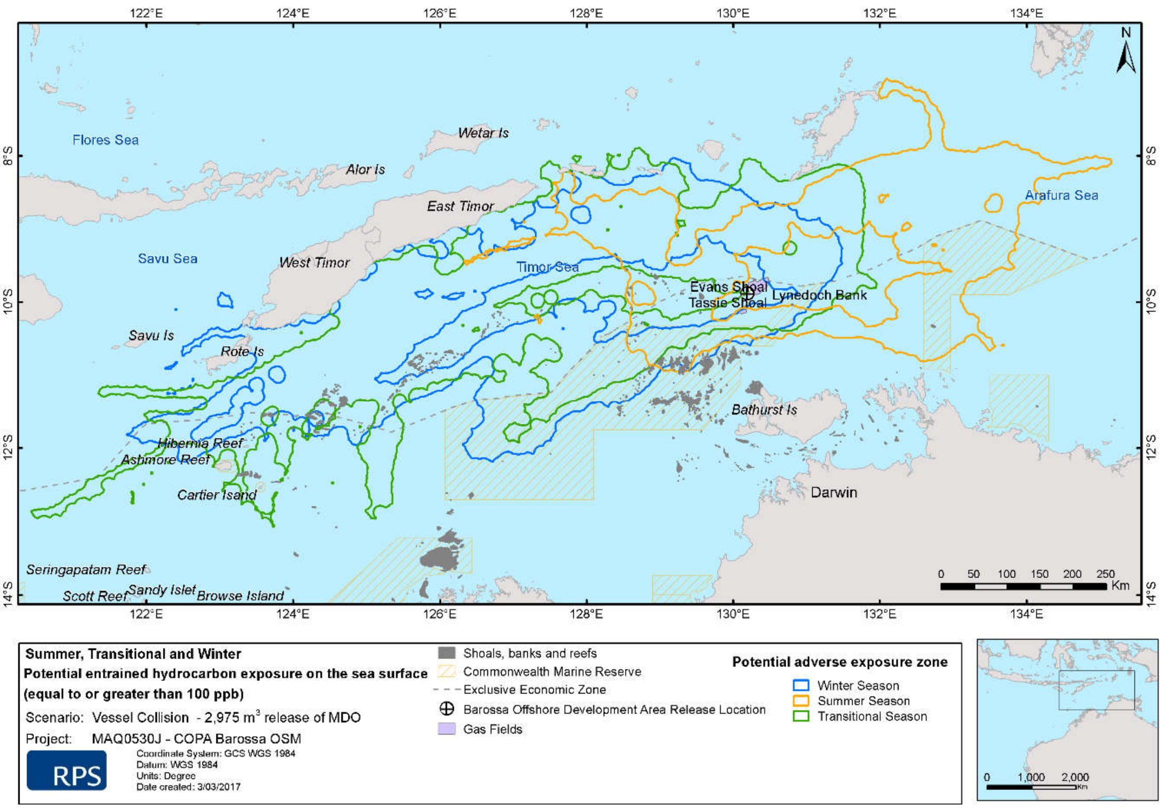


Figure 59 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for entrained hydrocarbons from a vessel collision releasing MDO (2,975 m^3)

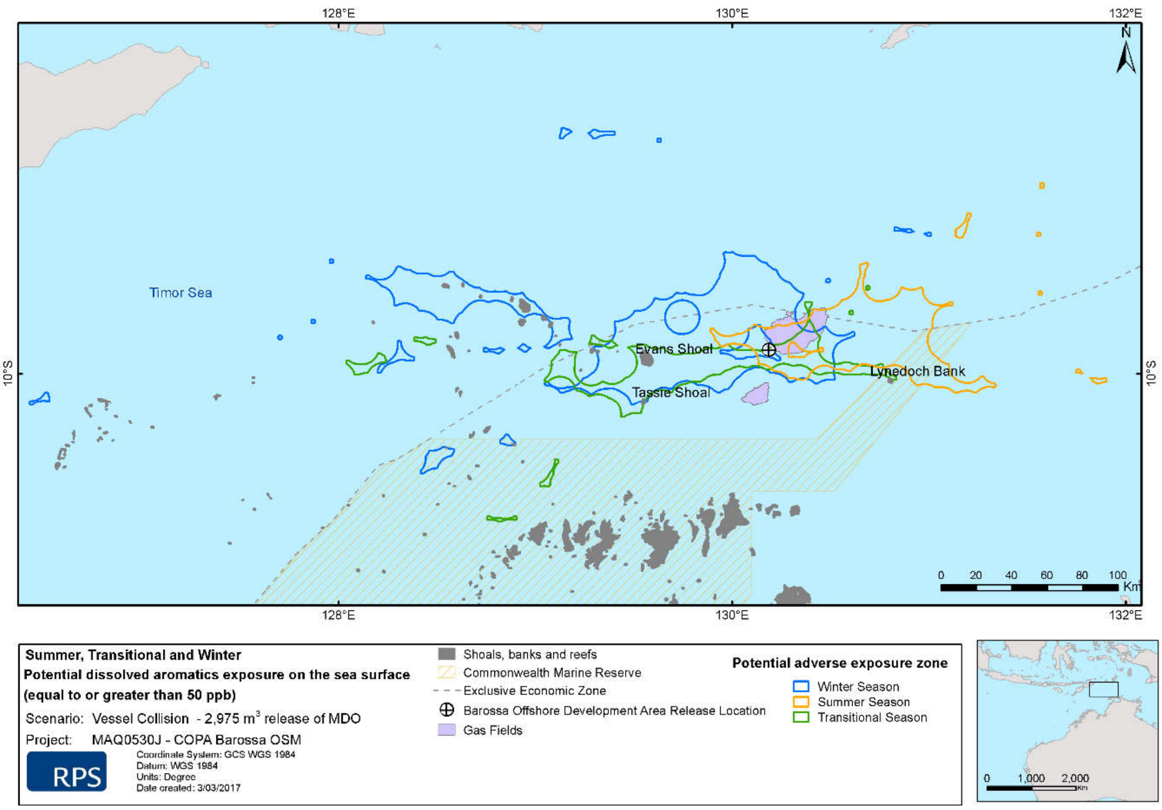


Figure 60 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for dissolved aromatic hydrocarbons from a vessel collision releasing MDO (2,975 m^3)

3.3 Scenario 3: Vessel collision leading to loss of a single FPSO facility condensate storage tank (19,400 m^3 Barossa condensate)

3.3.1 Single trajectory

Figure 61 shows the potential sea surface hydrocarbon exposure zones over the entire 40 day model simulation. The spill starting at 8 pm 25th June 2014 was used an example trajectory to illustrate the potential exposure by entrained and dissolved aromatic hydrocarbons to nearby shoals/banks during the winter season.

Figure 62 and Figure 63 display the potential dissolved aromatic and entrained hydrocarbon exposure zones, respectively.

Condensate on the sea surface was predicted to drift west of the release location, with low condensate exposure diverting northwest for a brief period before falling below the minimum reporting threshold. Low condensate sea surface exposure was predicted up to 264 km away, whereas moderate exposure was observed a maximum of 49 km from the release location. The entrained and dissolved aromatic hydrocarbons were shown to travel in more variable directions, as they moved with ocean currents. Low, moderate and high entrained hydrocarbons were recorded up to 707 km, 441 km and 60 km, respectively, from the release location. Low, moderate and high dissolved aromatics were observed up to 274 km, 250 km and 30 km, respectively, from the release location.

Figure 64 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that the condensate rapidly evaporates and by day 5 approximately 83% of the total spill volume (16,199 m^3) had evaporated. At the end of the simulation (day 40) approximately 88% (17,005 m^3) had evaporated, 4% (818 m^3) remained entrained in the water column and 8% (1,511 m^3) had decayed.

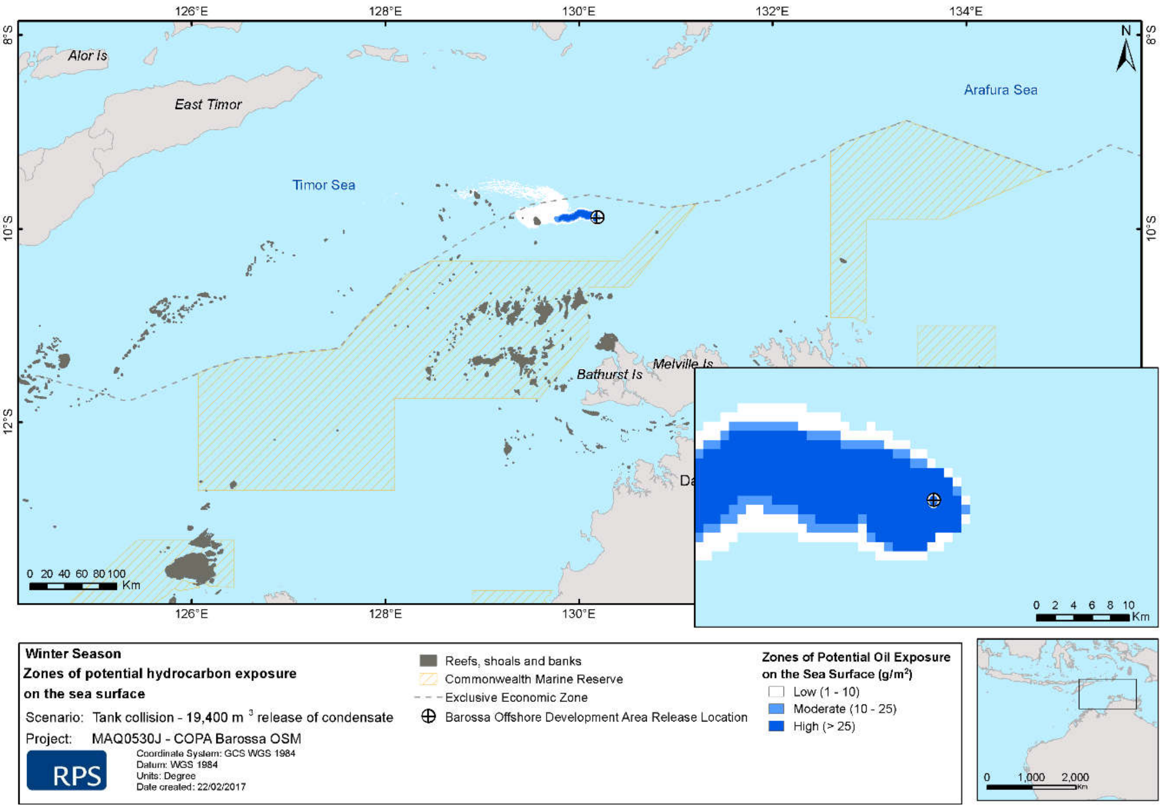


Figure 61 Single spill trajectory outputs showing the potential sea surface exposure zones (19,400 m^3 Barossa condensate)

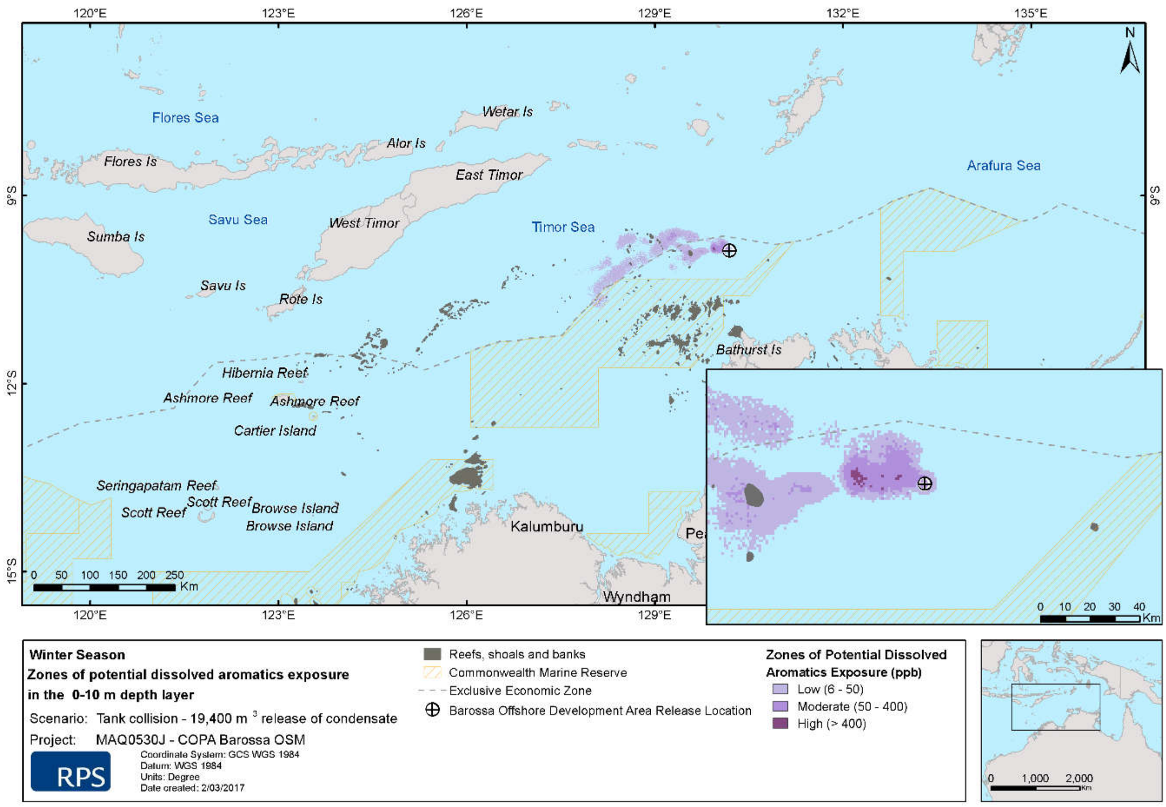


Figure 62 Single spill trajectory outputs showing the potential entrained exposure zones (19,400 m³ Barossa condensate)

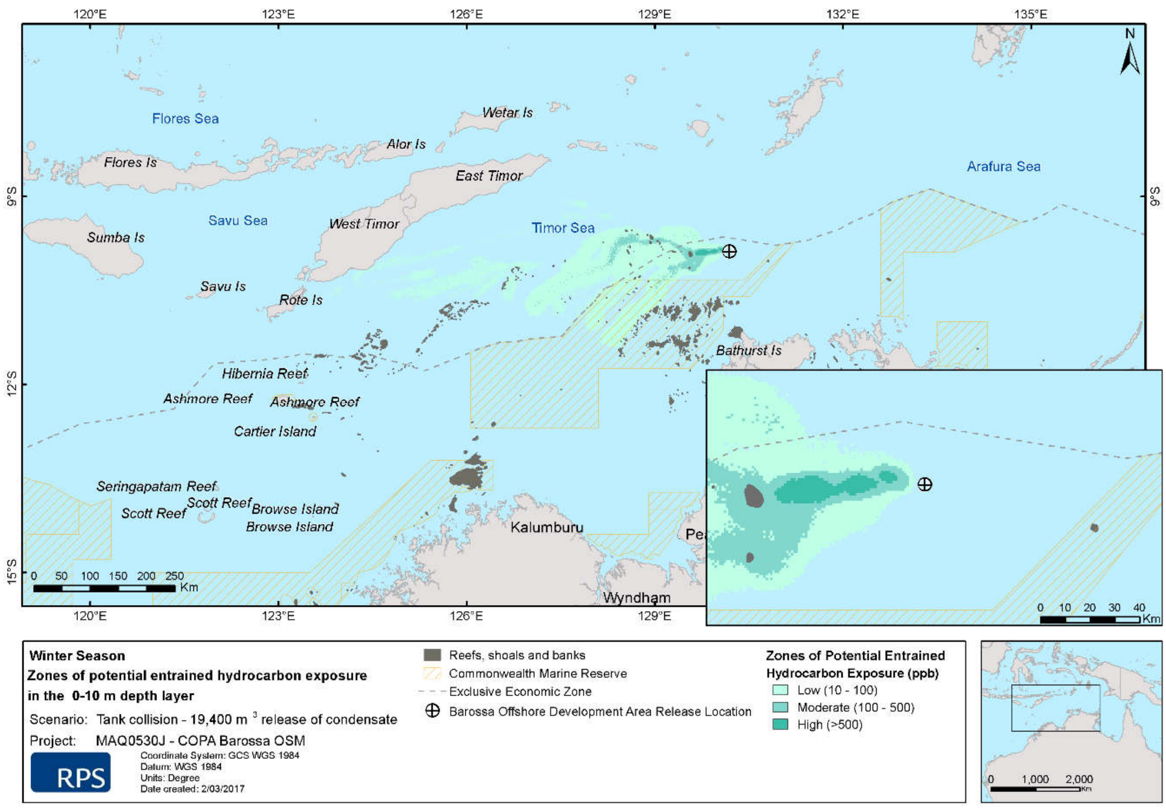


Figure 63 Single spill trajectory outputs showing the potential dissolved aromatic exposure zones (19,400 m³ Barossa condensate)

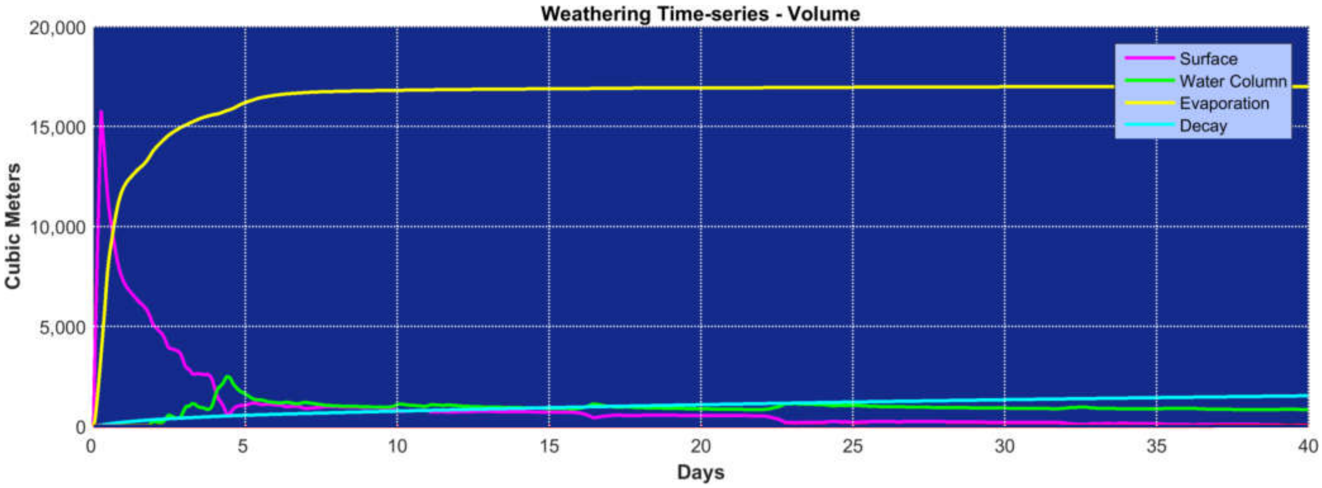


Figure 64 Predicted weathering and fates graph for the example spill trajectory from a 19,400 m^3 surface release of Barossa condensate from a storage tank rupture (tracked for 40 days)

3.3.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, the released hydrocarbons tended to initially travel east of the release location before travelling in variable directions, whereas during the transitional and winter seasons hydrocarbons were directed more towards the west. Weaker wind speeds during the transitional season resulted in less entrainment, consequently spills during this season travelled greater distances on the sea surface.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 320 km, 560 km and 303 km during summer, transitional and winter conditions, respectively (Table 23)
- contact was predicted (1–13% probability) by sea surface films within the adverse exposure zone with the surface waters above a number of submerged shoals/banks (total of 14), KEFs of the carbonate bank and terrace system of Van Diemen Rise and pinnacles of the Bonaparte Basin, and the open waters of the Oceanic Shoals CMR, depending on the season (Table 24).
- Figure 65 to Figure 67 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 74 shows the potential sea surface adverse exposure zone for all seasons.
- during summer conditions, the surface waters above Tassie Shoal recorded the highest probability of contact for submerged receptors with the sea surface adverse exposure zone (7%) while during transitional and winter conditions the waters above Evans Shoal was predicted to have the highest probability of contact with the sea surface adverse exposure zone (13% and 4% respectively). The Oceanic Shoals CMR and carbonate bank and terrace system of Van Diemen Rise had contact probabilities of 5-6% and 2-6%, respectively, dependant on season.
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa offshore development area is located within the bounds of these features (Table 24).
- no residual hydrocarbons were predicted to accumulate on any shoreline in any season to levels that may affect sensitive receptors onshore.
- contact was predicted (1–7% probability) by entrained hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 24), Cartier Island, open waters of the Arafura, Ashmore Reef, Oceanic Shoals and Cartier Island CMRs, waters above the KEFs of the shelf break and slope of the Arafura

Shelf and tributary canyons of the Arafura Depression and waters of the Timor Reef Fishery, depending on the season (Table 25). Figure 52 to Figure 54 shows the potential entrained hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 59 shows the potential sea surface adverse exposure zone for all seasons.

- during transitional and winter conditions, Evans Shoal recorded the highest probability of contact for submerged receptors with the entrained adverse exposure zone (14% and 27% respectively). During summer conditions probabilities did not extend beyond 1% for submerged receptors.
- contact was predicted (1–36% probability) by dissolved aromatic hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 23), open waters of the Arafura and Ocean Shoals CMRs, waters above the KEFs of the shelf break and slope of the Arafura Shelf, and carbonate bank and terrace system of Van Diemen Rise, and waters of the Timor Reef Fishery, depending on the season (Table 26 and Figure 76). Figure 71 to Figure 73 show the potential dissolved aromatic hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 76 shows the potential sea surface adverse exposure zone for all seasons.
- during summer, transitional and winter conditions, Evans Shoal recorded the highest probability of contact with the dissolved aromatics adverse exposure zone for submerged receptors (8%, 18% and 36% respectively).
- no contact with the adverse exposure zone for sea surface or sub-surface hydrocarbons was predicted with the NT/WA coastline or adjacent islands (Table 24 to Table 26).

Table 23 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (19,400 m^3 Barossa condensate)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	393.6	319.6	317.7
	Direction	West-southwest	West	West
Transitional	Maximum distance travelled (km) by a spill trajectory	857.6	559.8	402.5
	Direction	West	West	West
Winter	Maximum distance travelled (km) by a spill trajectory	813.8	302.5	300.8
	Direction	West	West-southwest	West-southwest

Table 24 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (19,400 m^3 Barossa condensate)

Summer conditions (December to February)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	2	-	-	17.2	-	-
	Martin Shoal	2	2	-	10.1	11.3	-
	Sunrise Bank	1	1	-	11.8	12.9	-
	Troubadour Shoals	1	1	1	7.9	8.1	8.6
	Flinders Shoal	1	-	-	10.4	-	-
	Evans Shoal	10	4	2	2.5	2.5	2.6
	Tassie Shoal	10	7	6	6.3	6.5	6.5
	Franklin Shoal	1	1	-	10.4	10.5	-
	Blackwood Shoal	3	1	-	1.0	10.4	-
	Lynedoch Bank	12	3	-	3.0	7.0	-
	Margaret Harries Bank	2	2	-	28.2	28.3	-
	Bellona Bank	1	1	-	31.0	35.3	-
	Echo Shoals	1	-	-	35.4	-	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	6	-	-	13.0	-	-
	Calder Shoal	4	-	-	14.7	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	1	-	-	23.5	-	-
	Oceanic Shoals CMR	18	6	4	2.2	3.8	4.0

	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	13	4	4	2.4	2.5	2.5
	Pinnacles of the Bonaparte Basin	2	-	-	30.0	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Transitional conditions (March and September to November)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	12	5	-	6.3	6.4	-
	Loxton Shoal	11	1	-	5.7	5.8	-
	Martin Shoal	10	3	-	5.4	7.4	-
	Sunrise Bank	7	3	-	10.0	27.3	-
	Troubadour Shoals	11	6	-	6.0	6.3	-
	Flinders Shoal	18	6	-	3.0	3.1	-
	Evans Shoal	28	13	5	1.6	1.8	2.3
	Tassie Shoal	7	4	-	3.4	3.4	-
	Franklin Shoal	19	8	-	3.0	3.1	-
	Blackwood Shoal	14	5	-	2.9	3.7	-
	Lynedoch Bank	2	-	-	5.7	-	-
	Margaret Harries Bank	11	3	-	7.7	8.7	-
	Bellona Bank	11	1	-	15.7	28.1	-
	Echo Shoals	9	5	-	14.8	16.8	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	3	-	-	17.5	-	-
	Karmt Shoal	4	-	-	16.9	-	-
	Cootamundra Shoal	1	-	-	30.8	-	-
	Calder Shoal	1	-	-	32.8	-	-

	Sahul Bank	3	-	-	19.5	-	-
	Dillon Shoal	2	-	-	26.0	-	-
Emergent receptor	Indonesia	1	-	-	20.1	-	-
	East Timor	1	-	-	22.3	-	-
	Ashmore Reef	1	-	-	32.0	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	13	5	2	3.8	4.1	4.8
	Ashmore Reef CMR	2	-	-	32.0	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	9	2	1	2.0	2.2	2.4
	Pinnacles of the Bonaparte Basin	6	1	-	10.0	13.8	-
	Continental slope demersal fish communities	2	-	-	30.3	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Winter conditions (April to August)							
Receptor		**Maximum probability of hydrocarbon exposure on the sea surface (%)**			**Minimum time before receptor exposed to hydrocarbons on the sea surface (days)**		
		Low (1–10 g/m²)	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**	**Low (1–10 g/m²)**	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**
Submerged receptor	Sunset Shoal	2	-	-	7.0	-	-
	Loxton Shoal	3	-	-	6.3	-	-
	Martin Shoal	3	-	-	6.2	-	-
	Sunrise Bank	2	-	-	9.0	-	-
	Troubadour Shoals	5	-	-	7.1	-	-
	Flinders Shoal	5	1	-	3.8	8.2	-
	Evans Shoal	10	4	2	2.3	2.5	4.3
	Tassie Shoal	5	2	1	2.5	2.5	4.3
	Franklin Shoal	5	1	-	3.8	8.3	-
	Blackwood Shoal	5	0	-	3.2	-	-
	Lynedoch Bank	1	1	-	5.0	5.3	-
	Margaret Harries Bank	4	-	-	9.0	-	-

	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	1	-	-	24.2	-	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	24.3	-	-
	East Timor	1	-	-	35.3	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	8	5	3	3.7	3.7	3.7
	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	9	6	5	1.8	1.8	2.1
	Pinnacles of the Bonaparte Basin	2	1	1	10.8	11.2	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Table 25 Probability and minimum time before entrained hydrocarbon exposure for receptors assessed (19,400 m³ Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	1	1	-	13.9	17.6	-
	Martin Shoal	2	1	-	13.0	17.2	-
	Sunrise Bank	-	-	-	-	-	-
	Flinders Shoal	2	1	-	10.3	24.2	-
	Evans Shoal	3	-	-	18.8	-	-
	Tassie Shoal	5	-	-	4.2	-	-
	Franklin Shoal	1	-	-	10.3	-	-
	Blackwood Shoal	2	1	-	10.2	15.2	-
	Lynedoch Bank	35	-	-	2.9	-	-
	Margaret Harries Bank	3	1	-	25.2	29.6	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	8	1	-	18.6	19.7	-
	Troubadour Shoals	1	1	-	27.6	31.6	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	1	1	-	15.8	22.1	-
	Calder Shoal	-	-	-	-	-	-
	Britomart Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-

	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	1	1	-	13.2	14.5	-
CMR	Arafura CMR	41	15	1	10.3	11.7	17.2
	Oceanic Shoals CMR	49	31	13	1.2	1.4	1.5
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	2	1	-	15.7	16.7	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	3	-	-	11.7	-	-
	Shelf break and slope of the Arafura Shelf	2	-	-	0.04	-	-
	Carbonate bank and terrace system of Van Diemen Rise	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	3	1	-	0.04	0.04	-
Transitional conditions (March and September to November)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	16	1	-	9.0	12.3	-
	Loxton Shoal	17	-	-	8.8	-	-
	Martin Shoal	13	-	-	7.7	-	-
	Sunrise Bank	5	1	-	11.5	12.1	-
	Flinders Shoal	37	4	3	2.9	4.1	5.1
	Evans Shoal	38	14	1	1.6	2.0	3.7
	Tassie Shoal	9	1	-	3.3	4.8	-
	Franklin Shoal	27	1	-	2.9	3.4	-

	Blackwood Shoal	27	1	-	2.8	3.3	-
	Lynedoch Bank	11	-	-	4.4	-	-
	Margaret Harries Bank	25	4	-	7.6	8.9	-
	Bellona Bank	15	1	-	17.1	20.2	-
	Echo Shoals	22	2	-	17.5	18.7	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	31	7	-	6.1	7.4	-
	Big Bank Shoals	9	1	-	21.4	23.4	-
	Karmt Shoal	8	1	-	20.2	21.6	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Britomart Shoal	3	-	-	29.1	-	-
	Sahul Bank	5	1	-	32.5	36.5	-
	Dillon Shoal	4	-	-	33.5	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	1	1	-	21.5	25.1	-
Emergent receptor	Indonesia	2	1	-	31.1	35.4	-
	East Timor	1	1	-	35.4	37.8	-
	Hibernia Reef	1	-	-	38.2	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	3	-	-	20.8	-	-
CMR	Arafura CMR	11	2	-	3.6	4.0	-
	Oceanic Shoals CMR	26	11	2	2.1	2.4	3.5
	Arnhem CMR	-	-	-	-	-	-

	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	11	1	-	21.0	23;8	-
KEF	Tributary Canyons of the Arafura Depression	8	2	-	2.1	2.3	-
	Shelf break and slope of the Arafura Shelf	3	1	-	10.2	17.9	-
	Carbonate bank and terrace system of Van Diemen Rise	2	-	-	24.9	-	-
	Continental slope demersal fish communities	1	-	-	36.1	-	-
Fishery	Timor Reef Fishery (NT Managed)	4	2	-	0.04	0.04	-
Winter conditions (April to August)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	39	12	1	6.9	7.1	7.8
	Loxton Shoal	37	14	1	6.5	7.4	7.8
	Martin Shoal	37	8	1	5.8	6.2	6.5
	Sunrise Bank	24	1	-	9.5	9.7	-
	Flinders Shoal	47	30	7	3.3	3.9	4.2
	Evans Shoal	55	27	9	1.9	2.2	2.8
	Tassie Shoal	36	15	8	2.4	2.5	4.1
	Franklin Shoal	51	19	7	3.1	3.8	4.2
	Blackwood Shoal	51	22	6	2.8	3.1	3.7
	Lynedoch Bank	5	1	-	13.1	14.2	-
	Margaret Harries Bank	19	4	1	7.1	9.4	11.8
	Bellona Bank	19	6	1	14.3	15.3	17.3
	Echo Shoals	36	8	1	14.2	14.8	16.7
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	45	14	1	6.1	6.8	7.2
	Big Bank Shoals	18	4	-	18.7	33.9	-
	Karmt Shoal	19	3	-	19.1	19.6	-
	Cootamundra Shoal	1	1	-	30.1	31.6	-
	Calder Shoal	1	1	-	9.4	13.2	-

	Britomart Shoal	-	-	-	-	-	-
	Sahul Bank	22	4	-	23.3	27.5	-
	Dillon Shoal	11	7	-	25.1	26.3	-
	Barton Shoal	9	1	-	34.7	36.8	-
	The Boxers	1	-	-	30.8	-	-
	Fantome Shoal	5	-	-	30.9	-	-
	Mangola Shoal	6	-	-	23.2	-	-
	Jabiru Shoals	6	1	-	24.3	26.8	-
	Pee Shoal	5	-	-	25.3	-	-
	Vee Shoal	1	-	-	33.5	-	-
	Johnson Bank	3	-	-	34.8	-	-
	Woodbine Bank	1	-	-	15.9	-	-
Emergent receptor	Indonesia	12	8	1	14.7	15.2	16.3
	East Timor	8	3	-	23.2	28.5	-
	Hibernia Reef	2	-	-	34.3	-	-
	Ashmore Reef	1	-	-	35.6	-	-
	Cartier Island	1	-	-	37.8	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	22	14	5	3.5	3.5	3.6
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	1	-	-	35.4	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	4	1	-	0.04	0.04	-
	Carbonate bank and terrace system of Van Diemen Rise	2	-	-	2.4	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	7	2	-	0.04	0.04	-

Table 26 Probability and minimum time before dissolved aromatic hydrocarbon exposure for receptors (19,400 m^3 Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	5	1	-	10.2	18.2	-
	Loxton Shoal	2	1	-	9.1	15.3	-
	Martin Shoal	3	1	-	8.1	8.2	-
	Sunrise Bank	1	-	-	34.4	-	-
	Flinders Shoal	5	2	-	10.1	10.5	-
	Evans Shoal	12	8	-	2.8	8.3	-
	Tassie Shoal	10	4	-	7.0	8.8	-
	Franklin Shoal	4	1	-	10.1	14.1	-
	Blackwood Shoal	5	-	-	9.7	-	-
	Lynedoch Bank	19	4	-	3.2	3.4	-
	Margaret Harries Bank	7	2	-	23.1	24.3	-
	Bellona Bank	1	-	-	36.5	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	5	1	-	20.4	23.6	-
	Troubadour Shoals	5	1	-	8.6	30.3	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	2	-	-	15.8	-	-
	Calder Shoal	1	-	-	17.0	-	-
	Britomart Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-

	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	1	-	-	30.1	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	12	3	1	15.9	18.8	25.3
	Oceanic Shoals CMR	32	19	5	1.5	1.5	1.9
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	8	-	-	15.7	-	-
	Shelf break and slope of the Arafura Shelf	9	4	3	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	2	1	1	3.0	3.4	3.9
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	5	1	1	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	9	2	-	9.1	13.4	-
	Loxton Shoal	16	4	-	6.3	9.8	-
	Martin Shoal	14	6	1	5.8	9.1	24.7
	Sunrise Bank	14	5	-	11.1	12.6	-
	Flinders Shoal	29	9	1	3.0	3.8	3.9
	Evans Shoal	40	18	3	1.7	2.1	2.8
	Tassie Shoal	4	3	1	3.3	3.3	3.4
	Franklin Shoal	29	11	-	2.9	3.8	-

	Blackwood Shoal	26	9	1	3.4	3.4	3.4
	Lynedoch Bank	5	1	-	5.8	6.4	-
	Margaret Harries Bank	17	6	1	7.8	8.9	13.5
	Bellona Bank	12	3	-	16.3	21.4	-
	Echo Shoals	16	3	-	17.7	20.4	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	23	10	3	6.0	6.9	7.0
	Big Bank Shoals	5	2	-	19.7	24.2	-
	Karmt Shoal	11	5	-	20.4	24.2	-
	Cootamundra Shoal	3	1	-	24.9	27.0	-
	Calder Shoal	2	1	-	25.9	28.1	-
	Britomart Shoal	6	2	-	25.7	26.0	-
	Sahul Bank	9	2	-	25.8	28.0	-
	Dillon Shoal	3	2	-	28.8	29.5	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	1	-	-	31.2	-	-
	Mangola Shoal	1	-	-	32.2	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	1	-	-	32.8	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	2	1	-	24.1	34.4	-
Emergent receptor	Indonesia	2	1	-	23.5	38.8	-
	East Timor	1	-	-	30.9	-	-
	Hibernia Reef	1	-	-	31.2	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	2	-	-	20.7	-	-
CMR	Arafura CMR	6	2	1	3.8	4.9	5.0
	Oceanic Shoals CMR	18	6	1	2.8	3.6	4.5
	Arnhem CMR	1	-	-	33.7	-	-

	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	8	7	1	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	3	1	-	25.3	37.4	-
	Continental slope demersal fish communities	1	-	-	29.9	-	-
Fishery	Timor Reef Fishery (NT Managed)	9	4	2	0.04	0.04	0.04
Winter conditions (April to August)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	18	7	2	7.2	9.4	9.6
	Loxton Shoal	25	9	2	6.7	7.6	8.9
	Martin Shoal	21	11	2	5.9	6.5	9.1
	Sunrise Bank	25	9	2	9.6	10.5	15.9
	Flinders Shoal	42	23	4	3.5	3.7	3.8
	Evans Shoal	58	36	11	2.1	2.3	2.8
	Tassie Shoal	28	15	6	3.1	3.1	3.1
	Franklin Shoal	44	21	8	3.4	3.8	4.0
	Blackwood Shoal	45	22	5	2.9	3.1	3.4
	Lynedoch Bank	3	2	-	12.6	14.0	-
	Margaret Harries Bank	16	6	1	7.1	8.4	9.3
	Bellona Bank	16	5	-	15.0	16.4	27.4
	Echo Shoals	16	7	1	16.8	18.6	27.9
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	38	19	4	6.2	6.8	7.1
	Big Bank Shoals	11	2	-	20.7	22.3	-
	Karmt Shoal	11	5	1	21.3	22.3	23.0
	Cootamundra Shoal	1	1	-	30.2	32.2	-
	Calder Shoal	4	1	-	8.4	9.5	-

	Britomart Shoal	7	2	-	23.5	24.5	-
	Sahul Bank	8	1	-	23.8	33.2	-
	Dillon Shoal	2	-	-	35.1	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	4	2	-	15.4	16.2	-
Emergent receptor	Indonesia	2	2	1	28.0	28.0	28.3
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	3	2	-	3.5	3.5	-
	Oceanic Shoals CMR	10	4	1	3.5	3.8	4.2
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	9	5	1	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	3	2	-	2.6	2.6	2.6
	Continental slope demersal fish communities	1	-	-	38.3	-	-
Fishery	Timor Reef Fishery (NT Managed)	9	6	3	0.04	0.04	0.04

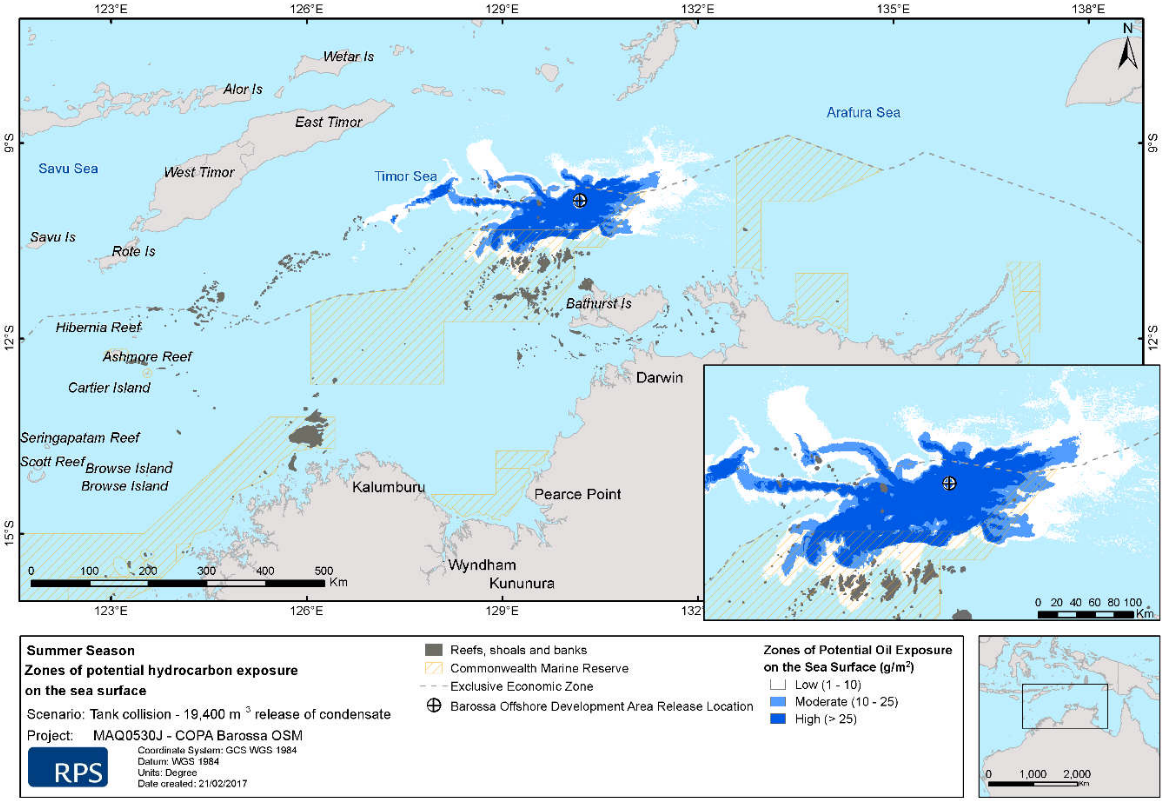


Figure 65 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (19,400 m^3 Barossa condensate)

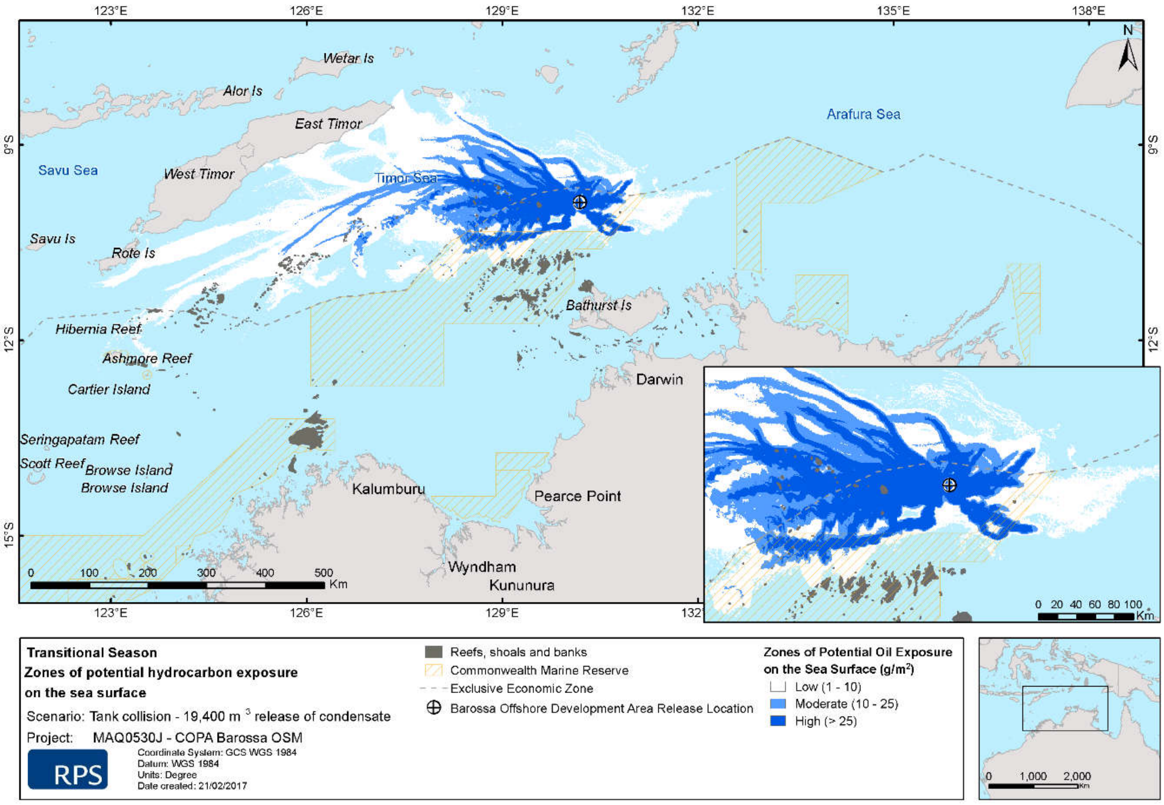


Figure 66 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (19,400 m^3 Barossa condensate)

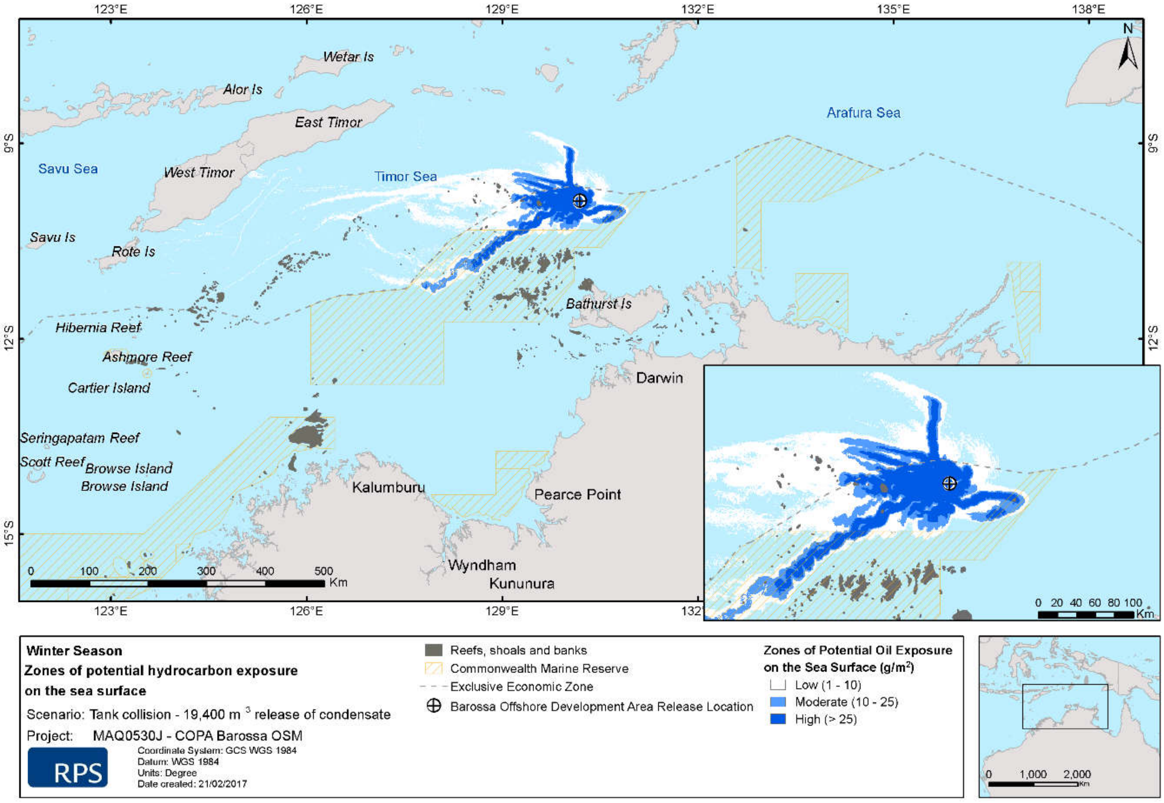


Figure 67 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (19,400 m³ Barossa condensate)

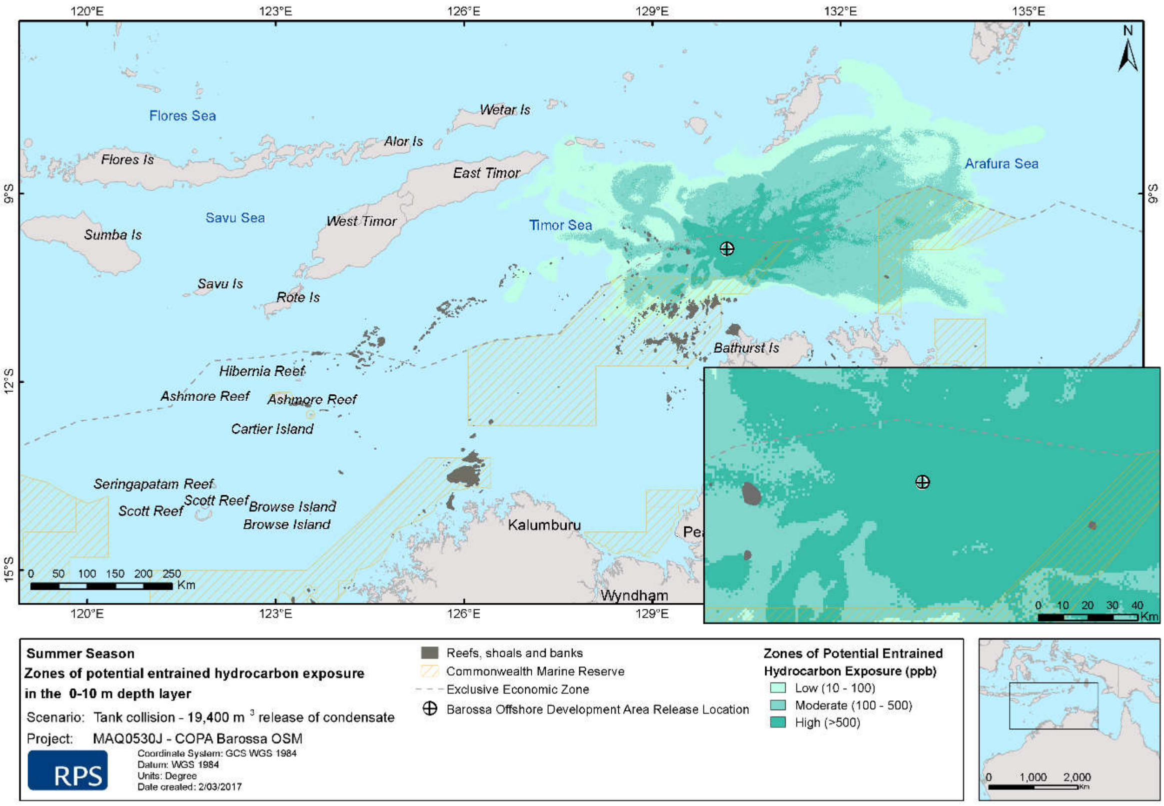


Figure 68 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (19,400 m³ Barossa condensate)

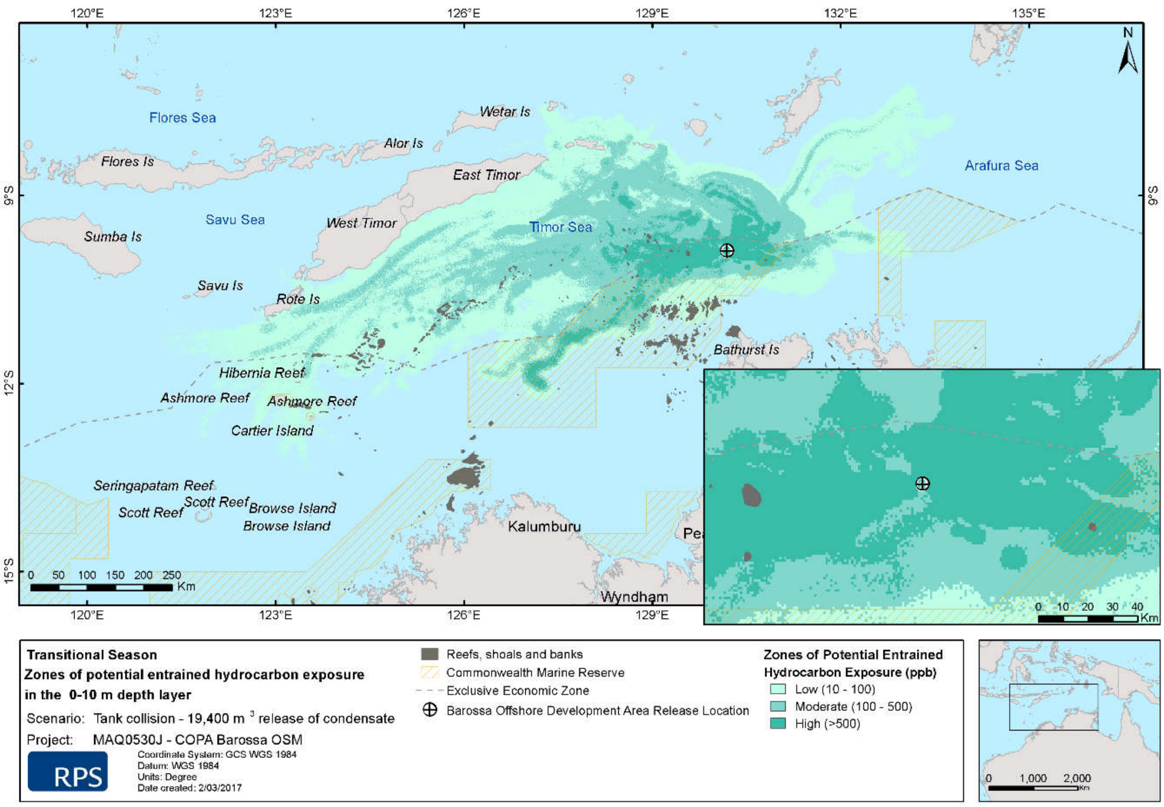


Figure 69 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (19,400 m³ Barossa condensate)

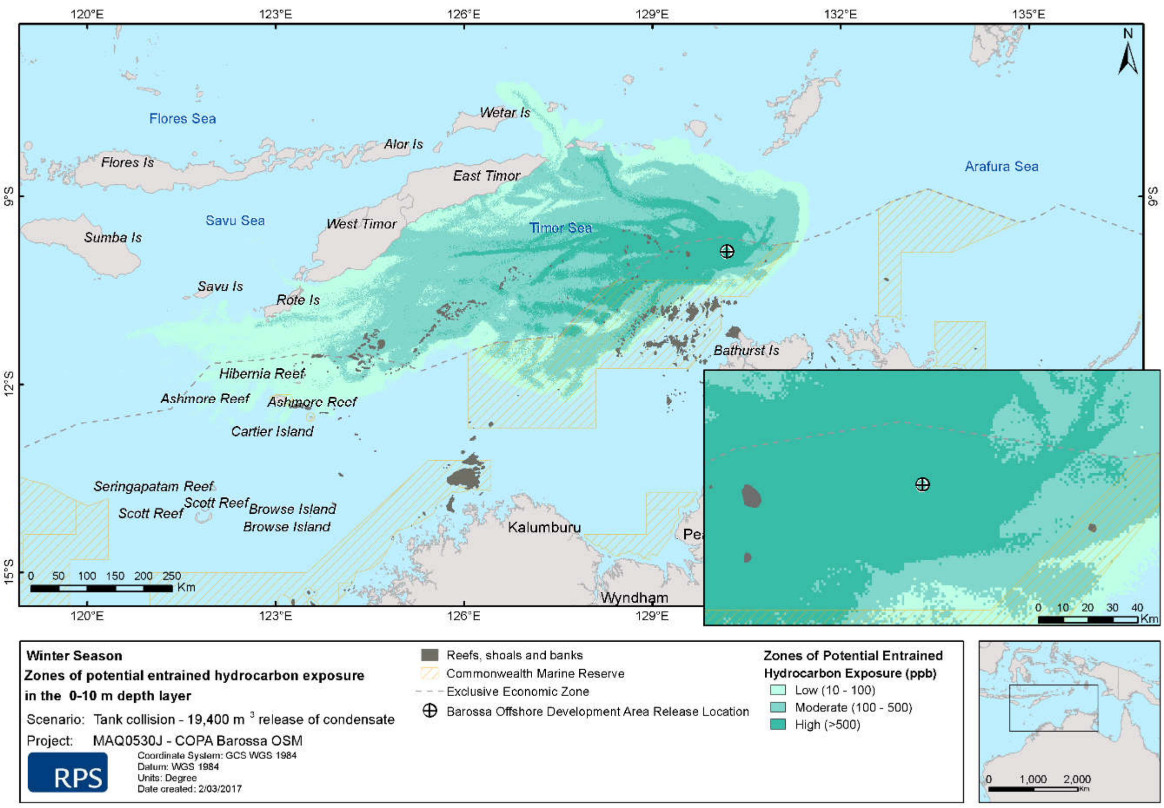


Figure 70 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (19,400 m³ Barossa condensate)

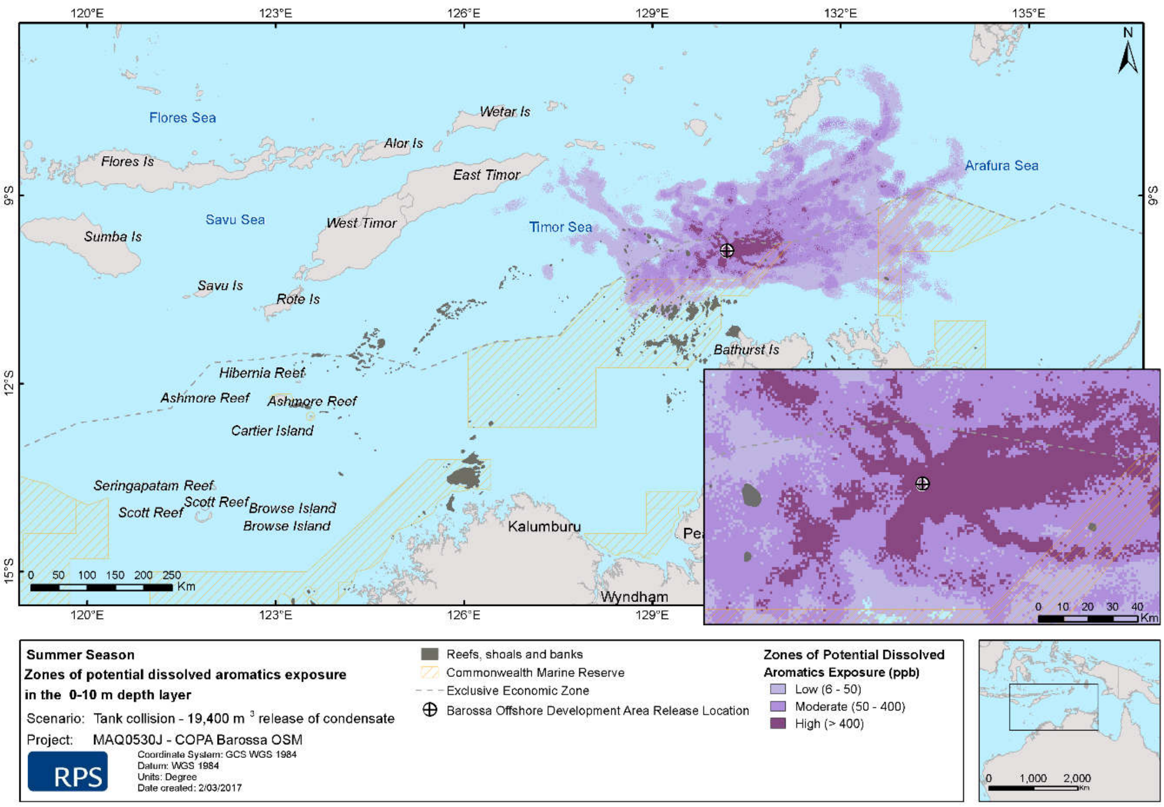


Figure 71 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (19,400 m^3 Barossa condensate)

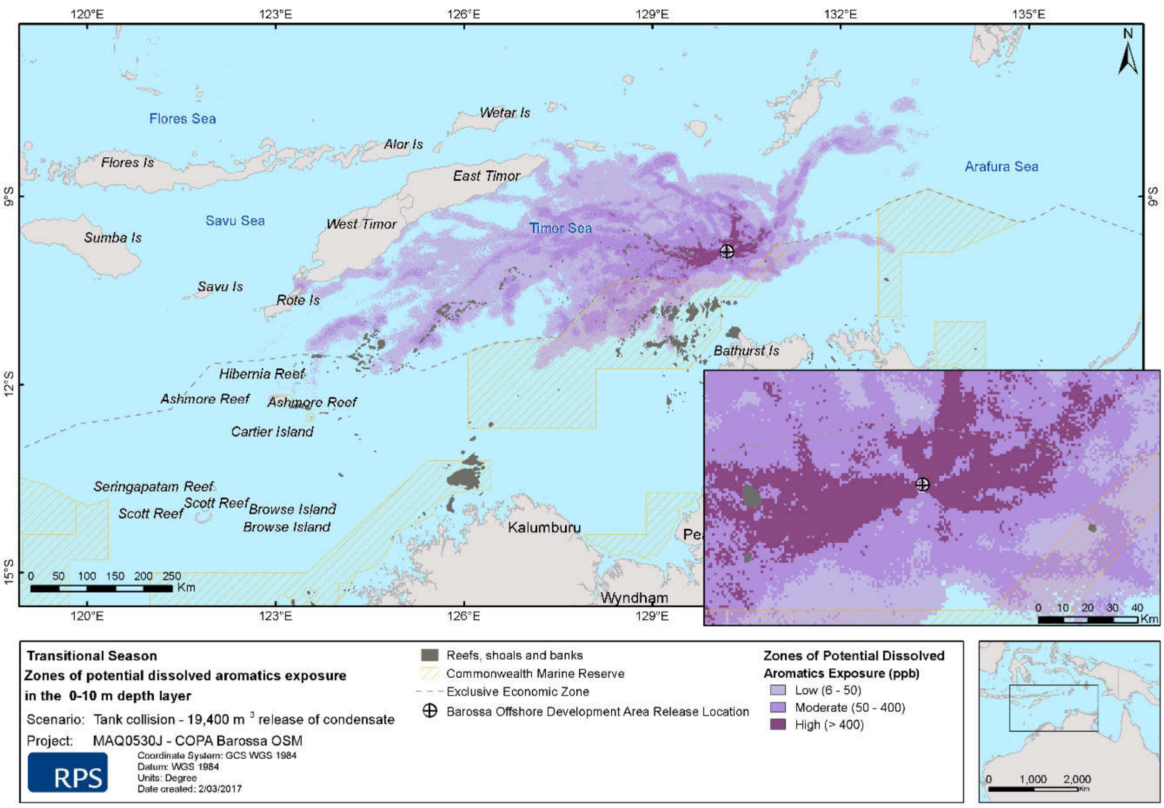


Figure 72 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (19,400 m^3 Barossa condensate)

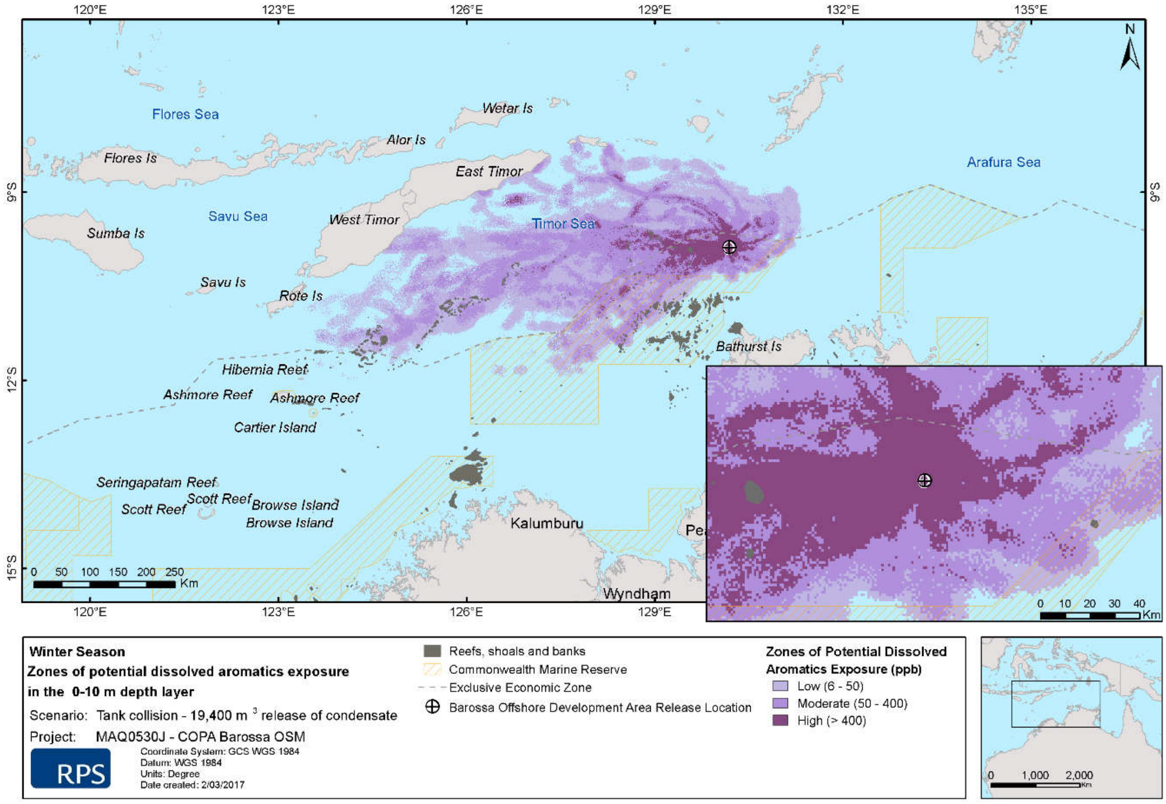


Figure 73 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (19,400 m^3 Barossa condensate)

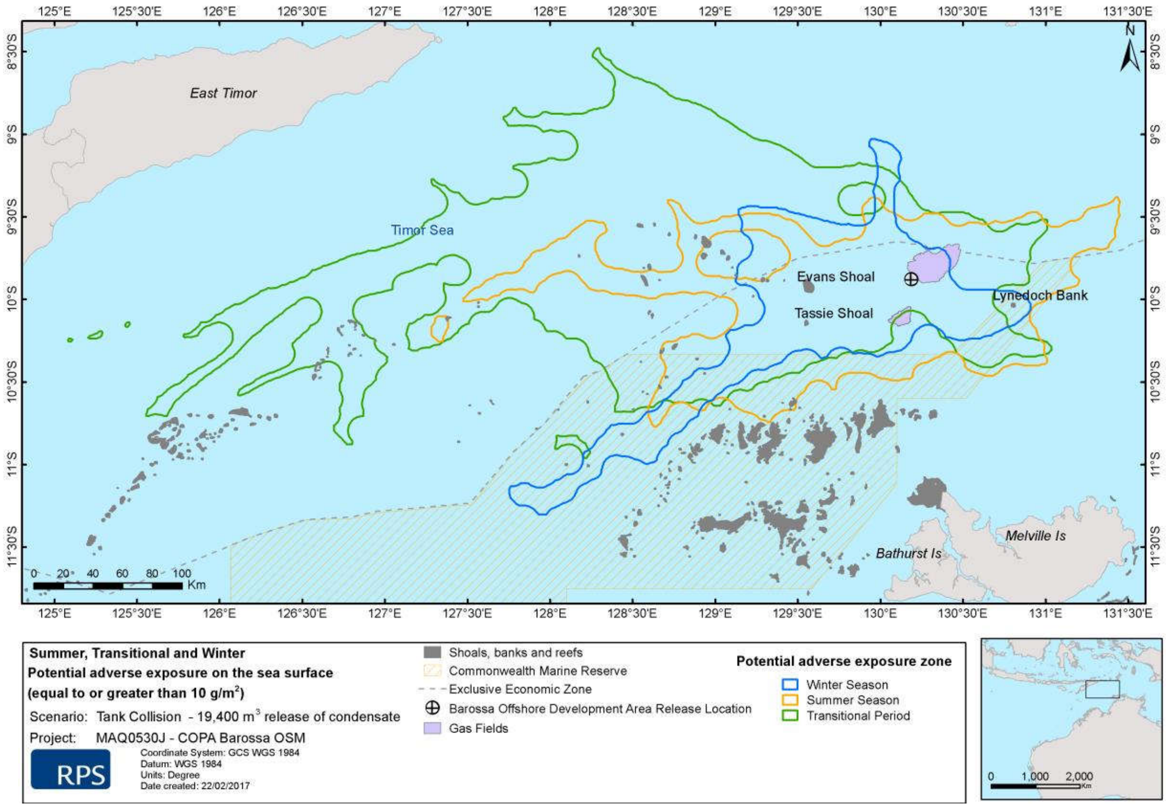


Figure 74 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a vessel collision releasing Barossa condensate (19,400 m^3)

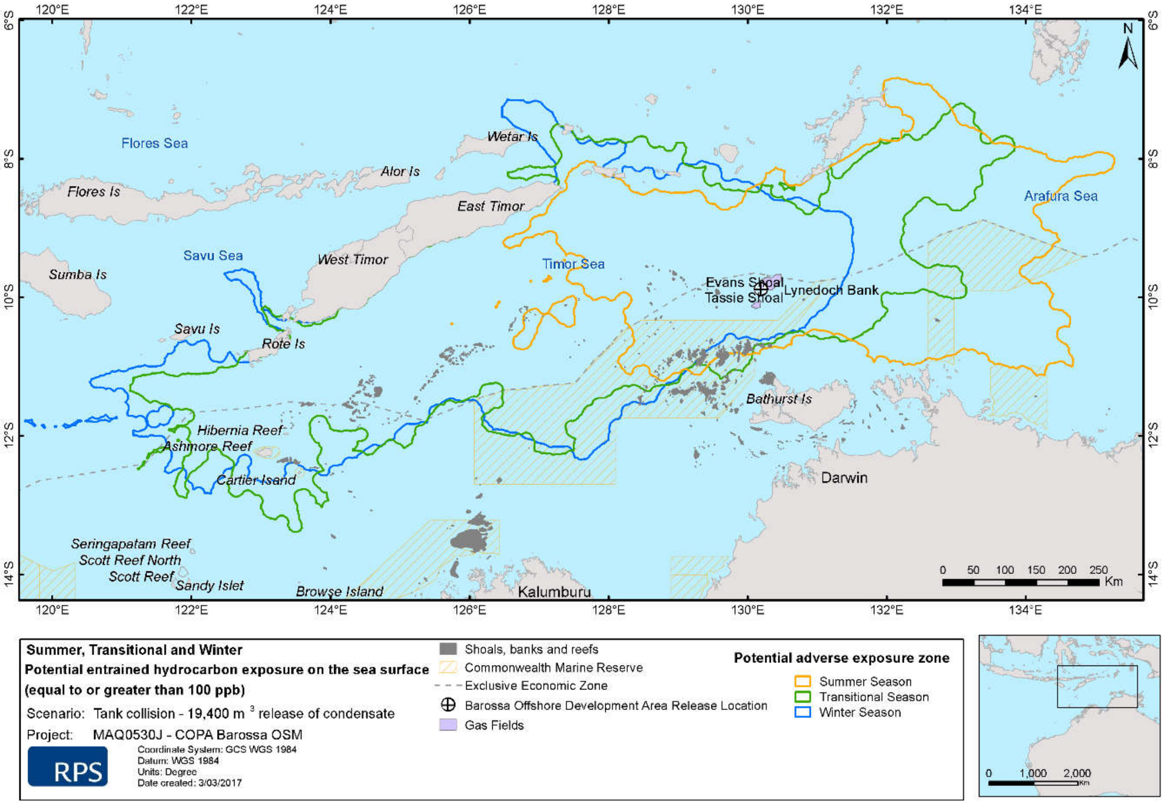


Figure 75 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for entrained hydrocarbons from a vessel collision releasing Barossa condensate (19,400 m^3)

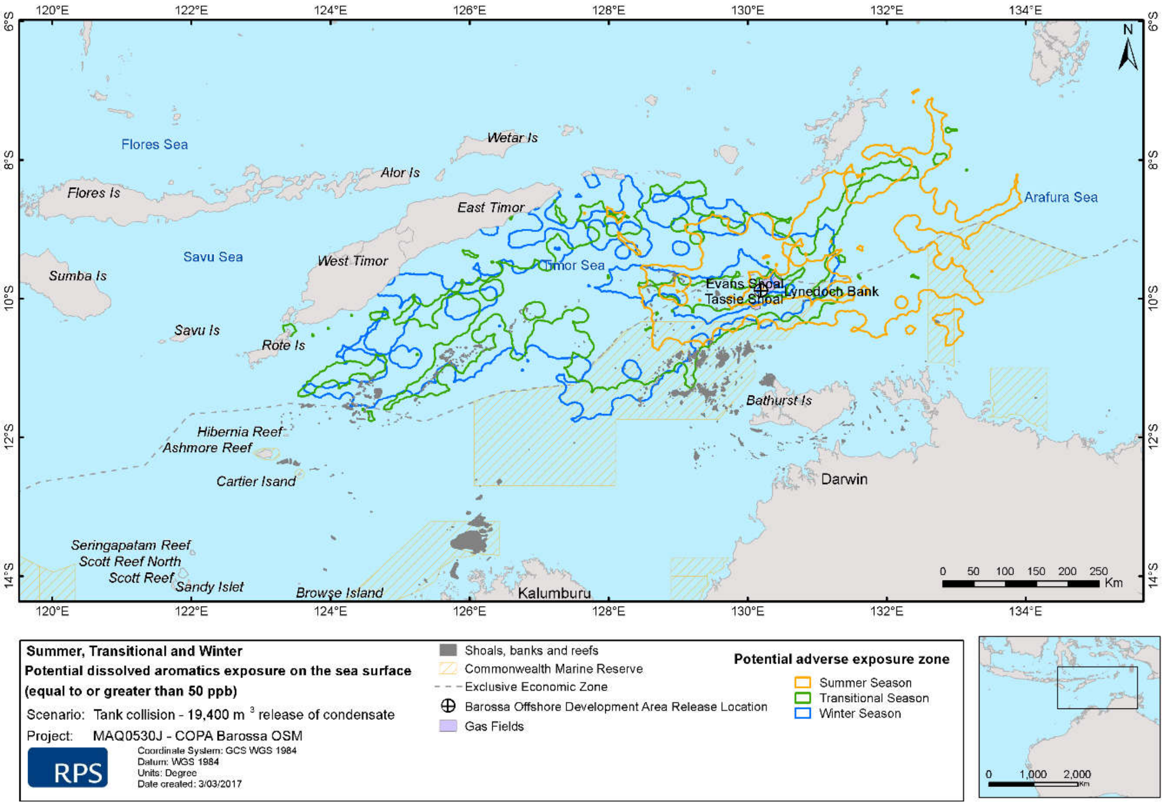


Figure 76 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for dissolved aromatic hydrocarbons from a vessel collision releasing Barossa condensate (19,400 m^3)

3.4 Scenario 4: Long-term well blowout (16,833 m³ Barossa condensate)

3.4.1 Single trajectory

Figure 77 shows the potential sea surface hydrocarbon exposure over the entire 90 day model simulation. The spill starting at 8 pm 25th June 2014 was chosen as an example trajectory to illustrate the potential exposure by entrained and dissolved aromatic hydrocarbons to nearby shoals/banks.

Figure 78 and Figure 79 display the potential entrained and dissolved aromatic hydrocarbon exposure zones.

As condensate rose to the sea surface from the subsea well blowout, the spill travelled west and northwest of the release location. Low condensate exposure on the sea surface was predicted up to 381 km away, whereas moderate exposure was limited to within 2 km. The in-water entrained hydrocarbons and dissolved aromatics were shown to move west and from the release location. Low, moderate and high entrained hydrocarbon was recorded up to 1,105 km, 580 km and 215 km, respectively, from the release location. Low, moderate and high dissolved aromatics were observed up to 707 km, 75 km and 5 km, respectively, from the release location.

Figure 80 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that the condensate remains entrained in the water column, whereby gradual and persistent decay occurs. At the end of the simulation (day 90) approximately 28% (4,706 m³) remained entrained in the water column and 46% (7,789 m³) had decayed.

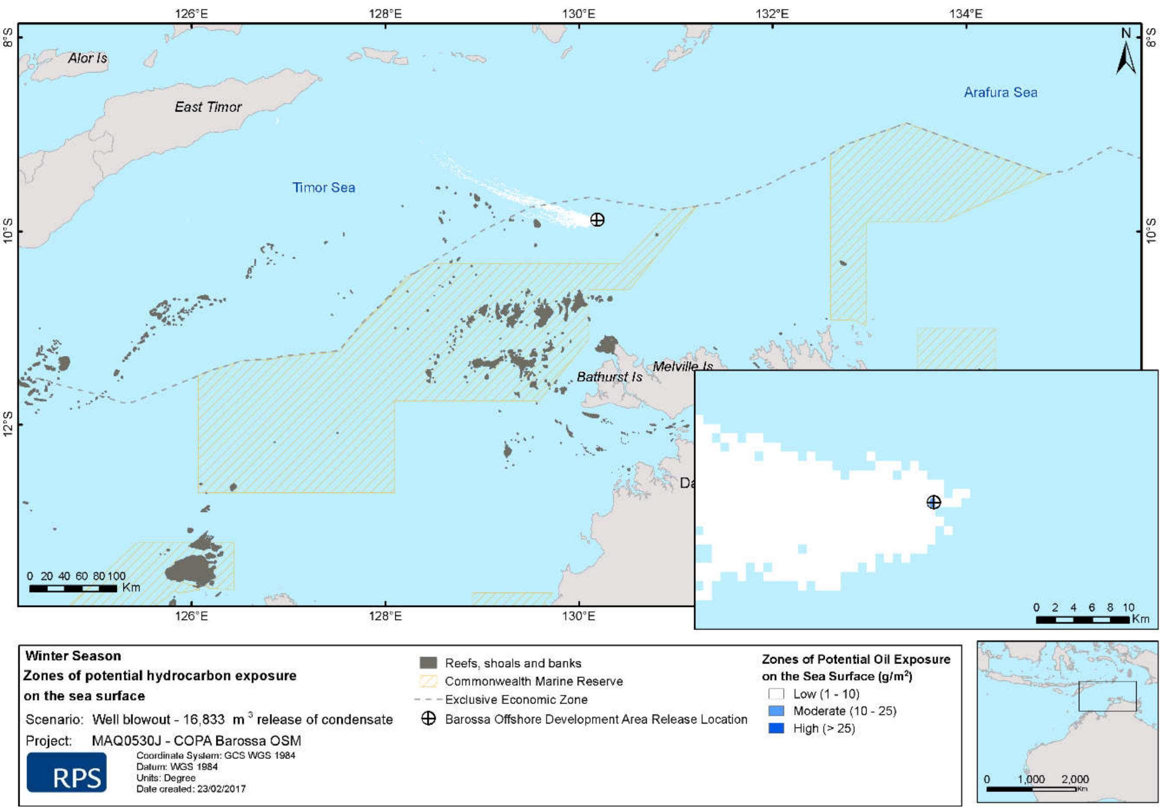


Figure 77 Single spill trajectory outputs showing the potential sea surface exposure zones (16,833 m³ Barossa condensate)

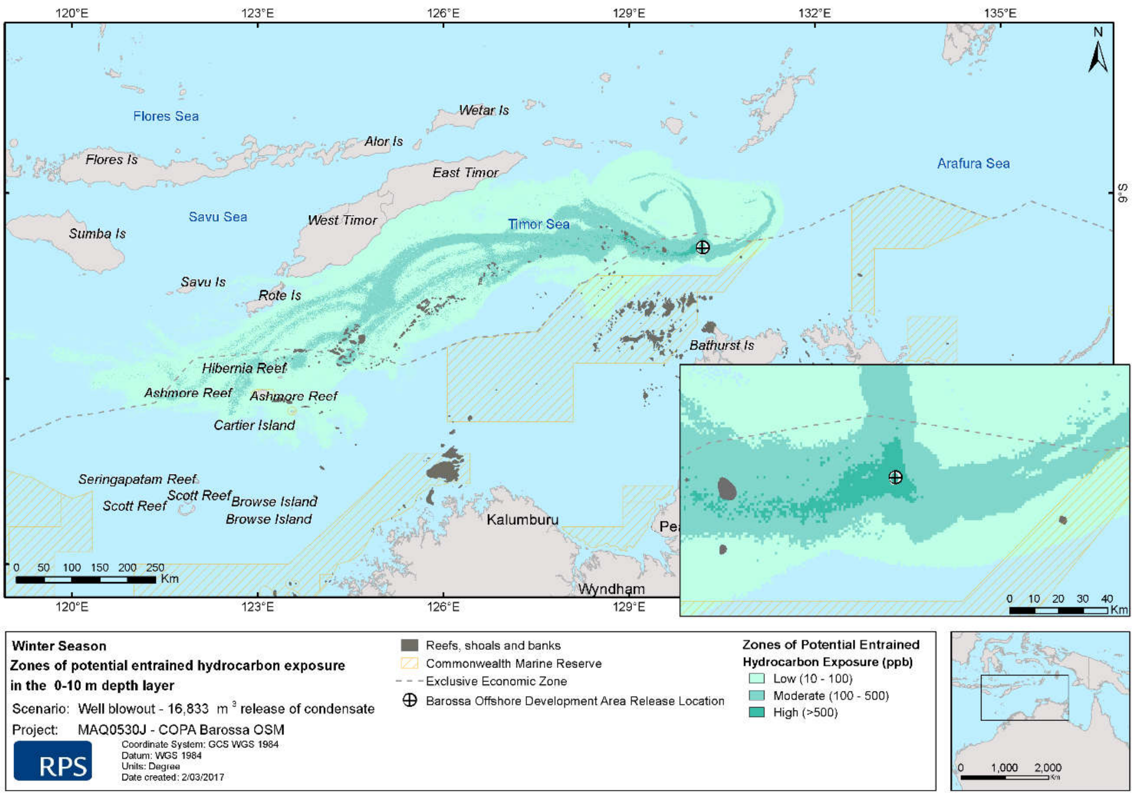


Figure 78 Single spill trajectory outputs showing the potential entrained exposure zones (16,833 m^3 Barossa condensate)

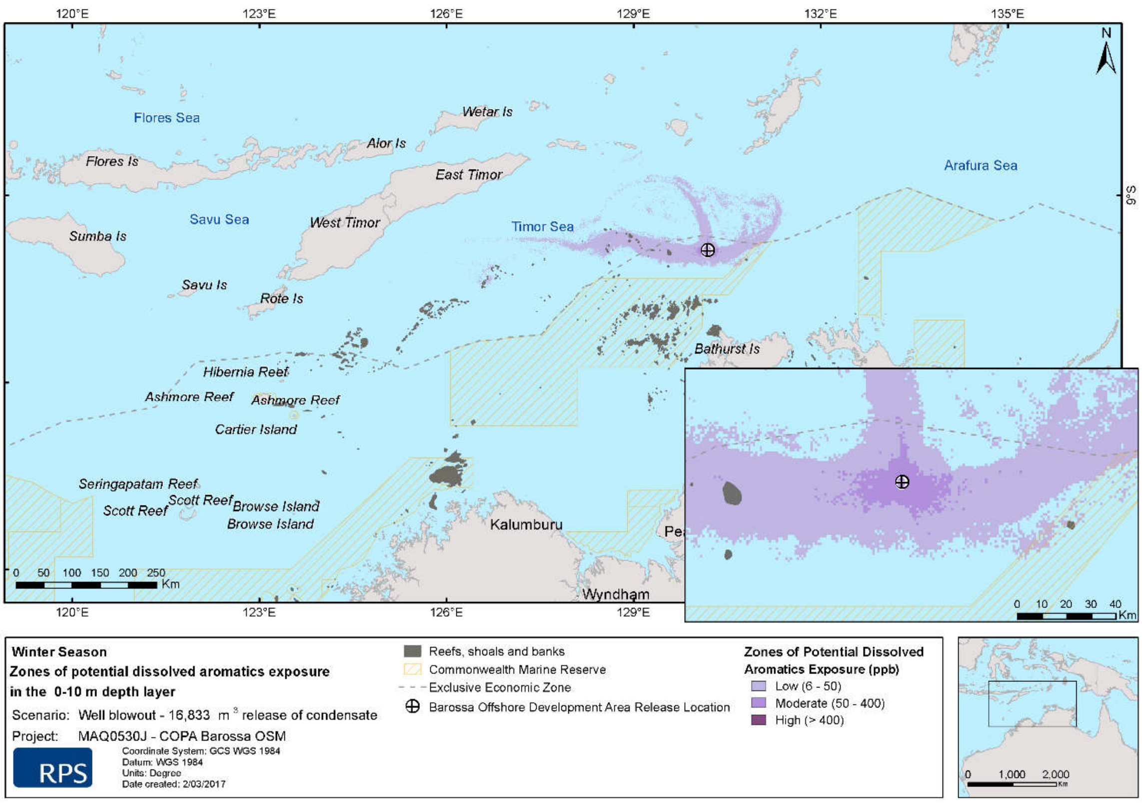


Figure 79 Single spill trajectory outputs showing the potential dissolved aromatic exposure zones (16,833 m^3 Barossa condensate)

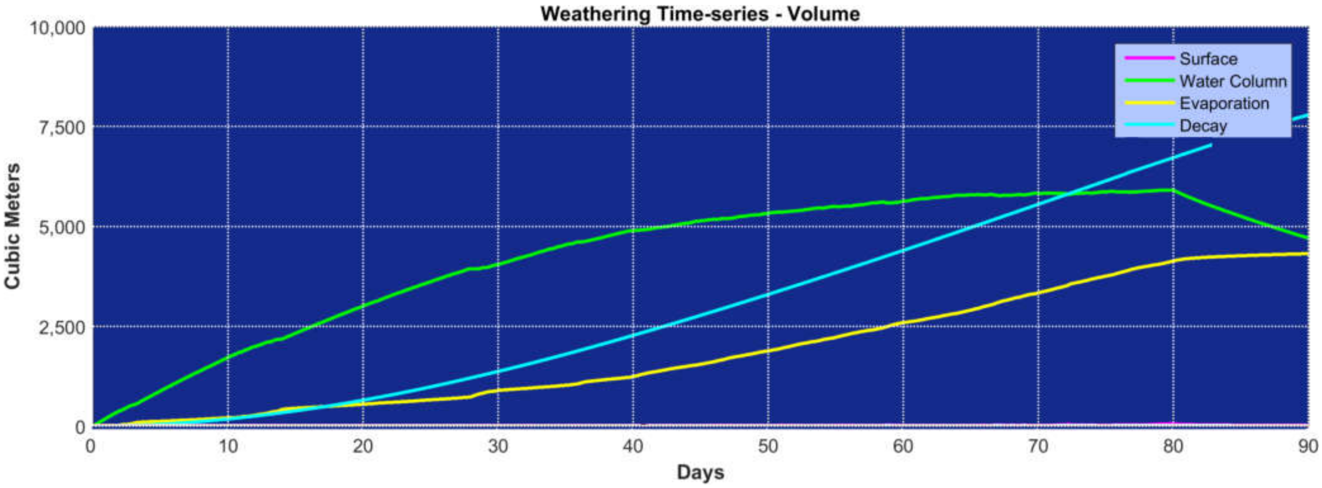


Figure 80 Predicted weathering and fates graph for the example spill trajectory selected from a 16,833 m^3 subsea release of Barossa condensate from a long-term well blowout (tracked for 90 days)

3.4.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, the condensate tended to oscillate around the release location and drift east and west. While under the transitional and winter seasons it was directed to drift west.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 34 km (south-southwest), 227 km (west) and 17 km (east-northeast) during summer, transitional and winter conditions, respectively (Table 27).
- low probability of contact predicted (3%) by sea surface films within the adverse exposure zone with the surface waters above the KEF of the carbonate bank and terrace system of Van Diemen Rise during summer and transitional conditions only (Table 28). Figure 81 to Figure 83 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 90 shows the potential sea surface adverse exposure zone for all seasons.
- no contact with waters above the various submerged banks/shoals for the sea surface adverse exposure zone was predicted during any seasonal conditions.
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa offshore development area is located within the bounds of these features (Table 28).
- no residual hydrocarbons were predicted to accumulate on any shoreline in any season to levels that may affect sensitive receptors onshore.
- contact was predicted (1–90% probability) by entrained hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 35), Ashmore Reef, Cartier Island, Hibernia Reef, North and South Scott Reef, open waters of the Oceanic Shoals, Arafura, Ashmore Reef, Arnhem, Cartier Island and Kimberley CMRs, KEFs of the shelf break and slope of the Arafura Shelf, carbonate bank and terrace system of Van Diemen Rise, carbonate bank and terrace system of Sahul Shelf, pinnacles of the Bonaparte Basin and continental slope demersal fish communities, and waters of the Timor Reef Fishery, depending on the season (Table 29). Figure 84 to Figure 86 shows the potential entrained hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 91 shows the potential sea surface adverse exposure zone for all seasons.
- during all seasons, Flinders Shoal recorded the highest probability of contact by entrained hydrocarbons at the adverse exposure zone (51% during summer conditions, 86% during transitional and 90% during winter conditions).

- contact was predicted (1–74% probability) by dissolved aromatic hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 31), Ashmore Reef, Hibernia Reef, open waters of the Oceanic Shoals, Arafura, Kimberley and Ashmore Reef CMRs, waters above the KEFs of the shelf break and slope of the Arafura Shelf, carbonate bank and terrace systems of Van Diemen Rise, carbonate bank and terrace system of and Sahul Shelf, tributary canyons of the Arafura Depression, pinnacles of the Bonaparte Basin and continental slope demersal fish communities and waters of the Timor Reef Fishery, depending on the season (Table 30). Figure 87 to Figure 89 shows the potential dissolved aromatic hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 92 shows the potential sea surface adverse exposure zone for all seasons.
- during transitional and winter conditions, Evans Shoal recorded the highest probability of contact with the dissolved aromatics adverse exposure zone (63 % during transitional and winter conditions 74%). Blackwood Shoal recorded the highest probability of contact with the dissolved aromatics adverse exposure zone during summer conditions (26%).
- no contact with the adverse exposure zone for sea surface or sub-surface hydrocarbons was predicted with the NT/WA coastline or adjacent islands (Table 28 to Table 30).

Table 27 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (16,833 m^3 Barossa condensate)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	584.2	33.7	3.6
	Direction	East	South-southwest	Northwest
Transitional	Maximum distance travelled (km) by a spill trajectory	933.2	227.3	1.0
	Direction	West-southwest	West	North-northwest
Winter	Maximum distance travelled (km) by a spill trajectory	1,142.9	16.6	1.3
	Direction	West-southwest	East-northeast	South-southeast

Table 28 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (16,833 m^3 Barossa condensate)

Summer conditions (December to February)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	2	-	-	43.2	-	-
	Loxton Shoal	2	-	-	39.3	-	-
	Martin Shoal	2	-	-	44.4	-	-
	Sunrise Bank	-	-	-	-	-	-
	Troubadour Shoals	3	-	-	41.5	-	-
	Flinders Shoal	4	-	-	38.5	-	-
	Evans Shoal	7	-	-	10.1	-	-
	Tassie Shoal	9	-	-	8.4	-	-
	Franklin Shoal	1	-	-	71.2	-	-
	Blackwood Shoal	-	-	-	-	-	-
	Lynedoch Bank	5	-	-	48.8	-	-
	Margaret Harries Bank	3	-	-	28.6	-	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	15	-	-	5.5	-	-
KEF	Tributary Canyons of the Arafura Depression	1	-	-	82.2	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.1	0.1	0.2
	Carbonate bank and terrace system of Van Diemen Rise	24	3	-	4.3	14.7	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.08	0.08	0.08

Transitional conditions (March and September to November)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	11	-	-	33.4	-	-
	Loxton Shoal	9	-	-	37.5	-	-
	Martin Shoal	5	-	-	16.1	-	-
	Sunrise Bank	2	-	-	84.8	-	-
	Troubadour Shoals	7	-	-	34.0	-	-
	Flinders Shoal	15	-	-	4.5	-	-
	Evans Shoal	19	-	-	2.6	-	-
	Tassie Shoal	15	-	-	5.2	-	-
	Franklin Shoal	10	-	-	6.6	-	-
	Blackwood Shoal	12	-	-	25.6	-	-
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	7	-	-	35.9	-	-
	Bellona Bank	7	-	-	48.3	-	-
	Echo Shoals	2	-	-	69.6	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	3	-	-	58.2	-	-
Emergent receptor	Indonesia	2	-	-	62	-	-
	East Timor	2	-	-	49.2	-	-
CMR	Oceanic Shoals CMR	24	1	-	9.4	79.1	-
KEF	Tributary Canyons of the Arafura Depression	1	-	-	76.6	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	25	3	-	2.8	69.4	-
	Carbonate bank and terrace system of Sahul Shelf	1	-	-	78.6	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.1	0.1	0.1

Winter conditions (April to August)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	2	-	-	71.1	-	-
	Loxton Shoal	3	-	-	59.9	-	-
	Martin Shoal	3	-	-	46.8	-	-
	Sunrise Bank	1	-	-	38.4	-	-
	Troubadour Shoals	3	-	-	58.2	-	-
	Flinders Shoal	7	-	-	61.5	-	-
	Evans Shoal	11	-	-	29.8	-	-
	Tassie Shoal	4	-	-	59.8	-	-
	Franklin Shoal	4	-	-	61.5	-	-
	Blackwood Shoal	2	-	-	41.9	-	-
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	2	-	-	60.8	-	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	1	-	-	63.3	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	2	-	-	65.6	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	6	-	-	6	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	12	-	-	2.9	-	-
	Carbonate bank and terrace system of Sahul Shelf	1	-	-	81.1	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.1	0.1	0.1

Table 29 Probability and minimum time before entrained hydrocarbon exposure for receptors assessed (16,833 m^3 Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	50	7	-	5.0	8.5	-
	Loxton Shoal	48	3	-	4.5	4.5	-
	Martin Shoal	43	4	-	4.1	4.2	-
	Sunrise Bank	22	1	-	6.9	7.3	-
	Flinders Shoal	73	51	3	2.4	2.7	2.7
	Evans Shoal	84	44	3	0.9	0.9	2.2
	Tassie Shoal	82	42	3	2.9	3.2	4.3
	Franklin Shoal	72	22	-	2.3	2.6	-
	Blackwood Shoal	81	26	-	2.0	2.5	-
	Lynedoch Bank	81	21	-	2.4	2.6	-
	Margaret Harries Bank	58	10	1	6.8	7.2	10.4
	Bellona Bank	19	7	-	10.8	12.3	-
	Echo Shoals	22	5	-	14.0	14.1	-
	Money Shoal	17	1	-	19.3	33.4	-
	Troubadour Shoals	51	15	1	4.8	4.9	5.7
	Big Bank Shoals	19	7	-	16.4	18.2	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	21	9	-	18.2	19.4	-
	Cootamundra Shoal	28	2	-	11.9	13.2	-
	Calder Shoal	17	2	-	8.3	14.4	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	20	10	1	19.9	20.3	33.8
	Dillon Shoal	19	2	-	19.5	20.8	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	16	3	-	21.5	23.0	-

	The Boxers	-	-	-	-	-	-
	Fantome Shoal	13	1	-	26.6	53.3	-
	Mangola Shoal	12	2	-	24.5	30.7	-
	Jabiru Shoals	16	5	1	24.4	27.7	50.3
	Pee Shoal	13	5	-	28.1	38.2	-
	Vee Shoal	10	2	-	27.3	35.6	-
	Newby Shoal	-	-	-	-	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	-	-	-	-	-	-
	Flat Top Bank	-	-	-	-	-	-
	Deep Shoal 1	-	-	-	-	-	-
	Johnson Bank	8	5	-	39.0	41.9	-
	Woodbine Bank	7	3	-	38.3	42.0	-
	Barracouta Shoal	4	1	-	41.9	44.6	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	-	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	3	1	-	51.4	55.4	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	2	1	-	54.4	55.7	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	-	-	-	-	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	2	-	-	70.0	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-

	Echuca Shoal	1	-	-	83.7	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	48	14	1	15.0	16.7	19.9
	East Timor	25	7	-	21.3	24.1	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	11	3	-	29.8	37.2	-
	Ashmore Reef	10	5	-	34.4	39.2	-
	Cartier Island	5	1	-	41.2	46.5	-
	Seringapatam Reef	4	-	-	58.8	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	3	-	-	62.7	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	2	-	-	74.5	-	-
	Scott Reef South	2	-	-	69.6	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	65	29	6	10.9	11.7	13.5
	Oceanic Shoals CMR	100	68	11	1.3	1.3	2.2
	Arnhem CMR	11	1	-	23.3	27.6	-

	Ashmore Reef CMR	10	5	1	33.2	38.7	43.4
	Cartier Island CMR	6	2	-	41.2	46.5	-
	Kimberley CMR	1	-	-	72.5	-	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	3	-	-	57.6	-	-
KEF	Tributary Canyons of the Arafura Depression	1	-	-	12.5	-	-
	Shelf break and slope of the Arafura Shelf	4	-	-	0.04	-	-
	Carbonate bank and terrace system of Van Diemen Rise	1	-	-	0.9	-	-
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	7	2	1	30.2	38.7	51.7
Fishery	Timor Reef Fishery (NT Managed)	5	-	-	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	86	24	-	5.1	6.3	-
	Loxton Shoal	81	16	1	4.5	4.8	14.7
	Martin Shoal	85	17	-	4.1	4.3	-
	Sunrise Bank	65	9	-	6.7	7.0	-
	Flinders Shoal	99	86	11	2.5	2.7	3.4
	Evans Shoal	100	63	4	0.4	1.0	2.1
	Tassie Shoal	97	41	2	2.5	2.7	4.7
	Franklin Shoal	99	60	3	2.4	2.7	3.5
	Blackwood Shoal	100	51	-	2.4	2.4	-
	Lynedoch Bank	37	18	-	2.6	2.9	-
	Margaret Harries Bank	85	30	3	6.4	7.3	9.7
	Bellona Bank	56	4	-	10.6	12.3	-
	Echo Shoals	58	10	1	12.1	13.7	14.0
	Money Shoal	6	3	-	23.0	26.9	-

	Troubadour Shoals	91	41	1	4.6	5.3	6.2
	Big Bank Shoals	46	10	-	17.4	17.5	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	46	6	1	15.3	18.5	19.5
	Cootamundra Shoal	16	4	-	8.0	9.6	-
	Calder Shoal	16	2	-	7.6	8.3	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	49	12	5	18.1	19.9	20.7
	Dillon Shoal	43	3	-	18.6	19.8	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	38	7	-	21.7	23.3	-
	The Boxers	6	-	-	9.9	-	-
	Fantome Shoal	39	2	-	28.0	38.8	-
	Mangola Shoal	33	2	-	25.4	25.4	-
	Jabiru Shoals	42	5	-	26.0	26.2	-
	Pee Shoal	34	3	-	27.5	27.5	-
	Vee Shoal	20	1	-	29.2	35.1	-
	Newby Shoal	2	1	-	42.3	48.1	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	2	-	-	27.1	-	-
	Flat Top Bank	2	2	-	45.1	46.7	-
	Deep Shoal 1	1	-	-	28.9	-	-
	Johnson Bank	19	4	-	28.2	33.2	-
	Woodbine Bank	13	2	-	32.2	36.2	-
	Barracouta Shoal	8	1	-	41.5	47.8	-
	Gale Bank	1	-	-	37.1	-	-
	Van Cloon Shoal	2	1	-	37.0	41.3	-
	Favell Bank	1	-	-	40.1	-	-
	Vulcan Shoal	9	-	-	47.7	-	-

	Baldwin Bank	1	-	-	40.6	-	-
	Goeree Shoal	5	-	-	49.8	-	-
	Penguin Shoal	2	-	-	46.3	-	-
	Eugene McDermott Shoal	1	-	-	51.3	-	-
	Holothuria Banks	1	-	-	78.0	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	6	-	-	41.2	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	4	-	-	43.7	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	53	17	6	11.4	11.8	15.0
	East Timor	64	18	3	18.2	18.7	19.4
	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	25	2	-	29.7	31.5	-
	Ashmore Reef	26	3	-	31.0	39.9	-
	Cartier Island	12	2	-	31.0	47.6	-
	Seringapatam Reef	8	-	-	48.7	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-

	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	7	1	-	49.8	68.7	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	5	-	-	49.7	-	-
	Scott Reef South	6	1	-	48.6	72.2	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	6	-	-	46.2	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	17	12	9	11.8	13.6	17.2
	Oceanic Shoals CMR	90	71	24	1.5	1.7	2.0
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	27	3	-	30.2	34.5	-
	Cartier Island CMR	14	3	-	31.0	34.1	-
	Kimberley CMR	3	-	-	48.3	-	-
	Joseph Bonaparte CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	7	-	-	53.1	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	2	2	-	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	1	1	-	1.1	1.1	-
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	6	1	1	28.4	31.0	43.5
Fishery	Timor Reef Fishery (NT Managed)	3	-	-	0.04	-	-

Winter conditions (April to August)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged	Sunset Shoal	95	33	1	4.4	4.4	5.6

receptor	Loxton Shoal	97	36	1	3.9	4.2	6.1
	Martin Shoal	96	31	1	3.5	3.6	4.3
	Sunrise Bank	79	6	1	7.0	7.4	11.4
	Flinders Shoal	100	90	12	2.3	2.3	2.8
	Evans Shoal	100	72	3	1.1	1.5	1.9
	Tassie Shoal	98	42	1	1.6	1.6	2.9
	Franklin Shoal	100	60	1	2.4	2.4	3.4
	Blackwood Shoal	100	66	2	2.0	2.1	2.3
	Lynedoch Bank	34	3	1	5.9	7.6	17.1
	Margaret Harries Bank	97	29	1	5.0	5.0	8.5
	Bellona Bank	86	6	1	9.5	10.8	41.9
	Echo Shoals	99	23	1	9.9	12.3	13.9
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	100	38	1	4.8	5.5	6.3
	Big Bank Shoals	88	18	2	13.2	13.7	14.9
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	87	21	1	12.7	13.8	16.2
	Cootamundra Shoal	8	5	1	19.4	21.3	22.8
	Calder Shoal	16	3	1	7.9	23.7	28.5
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	90	30	3	14.5	16.7	18.4
	Dillon Shoal	82	12	1	14.7	17.5	17.5
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	65	8	-	16.1	19.8	21.6
	The Boxers	6	-	-	19.2	19.8	-
	Fantome Shoal	63	13	-	20.0	25.7	-
	Mangola Shoal	41	3	-	21.5	25.9	-
	Jabiru Shoals	54	4	-	22.0	32.4	-
	Pee Shoal	46	6	-	22.0	28.4	-

	Vee Shoal	48	-	-	23.2	29.5	-
	Newby Shoal	5	-	-	42.1	45.7	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	4	1	-	36.4	55.3	-
	Flat Top Bank	3	3	-	44.3	47.6	-
	Deep Shoal 1	5	1	-	40.4	49.0	-
	Johnson Bank	38	2	-	25.8	31.2	-
	Woodbine Bank	28	1	-	29.6	44.3	-
	Barracouta Shoal	8	-	-	36.3	-	-
	Gale Bank	1	-	-	65.2	-	-
	Van Cloon Shoal	3	-	-	57.8	-	-
	Favell Bank	-	-	-	69.2	-	-
	Vulcan Shoal	6	-	-	52.4	-	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	2	-	-	59.8	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	2	1	-	60.4	67.6	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	3	-	-	38.1	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	1	-	-	54.8	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent	Indonesia	65	15	-	14.9	15.2	-

receptor	East Timor	51	13	1	12.4	14.6	43.4
	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	56	2	-	25.1	27.2	-
	Ashmore Reef	41	3	-	29.2	30.6	-
	Cartier Island	32	1	-	32.2	32.5	-
	Seringapatam Reef	7	-	-	48.0	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	1	-	-	55.7	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	1	-	-	82.7	-	-
	Scott Reef South	4	-	-	60.3	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	1	-	-	47.6	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	88	54	5	1.1	2.2	4.2
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	44	3	-	26.3	30.3	-
	Cartier Island CMR	35	1	-	31.9	38.6	-
	Kimberley CMR	2	1	-	70.1	84.2	-
	Joseph Bonaparte Gulf CoCMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	4	-	-	40.7	-	-

KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	38	5	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	99	19	2	0.4	1.3	2.1
	Pinnacles of the Bonaparte Basin	61	7	1	8.5	8.5	10.6
	Carbonate bank and terrace system of Sahul Shelf	15	4	-	21.3	23.5	28.9
Fishery	Timor Reef Fishery (NT Managed)	100	38	5	0.04	0.04	0.04

Table 30 Probability and minimum time before dissolved aromatic hydrocarbon exposure for receptors (16,833 m³ Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	25	7	-	8.9	10.4	-
	Loxton Shoal	23	9	-	4.8	5.0	-
	Martin Shoal	21	4	-	4.2	4.3	-
	Sunrise Bank	11	1	-	8.0	9.9	-
	Flinders Shoal	48	18	1	2.8	2.8	3.4
	Evans Shoal	72	25	3	1.1	1.1	1.2
	Tassie Shoal	10	18	1	2.4	2.6	4.0
	Franklin Shoal	49	19	1	2.7	2.8	3.4
	Blackwood Shoal	56	26	1	2.4	2.4	10.4
	Lynedoch Bank	48	23	-	1.6	2.5	-
	Margaret Harries Bank	20	6	-	7.3	8.7	-
	Bellona Bank	9	2	-	12.8	12.9	-
	Echo Shoals	7	1	-	17.5	18.5	-
	Money Shoal	5	-	-	34.1	-	-
	Troubadour Shoals	29	8	-	5.5	5.5	-
	Big Bank Shoals	8	1	-	19.4	19.6	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	12	2	-	19.8	20.6	-
	Cootamundra Shoal	13	3	-	12.5	15.8	-
	Calder Shoal	5	2	-	7.4	7.4	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	5	1	-	21.0	21.6	-
	Dillon Shoal	7	1	-	20.9	29.0	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	4	1	-	24.3	24.4	-

	The Boxers	-	-	-	-	-	-
	Fantome Shoal	2	1	-	35.1	39.5	-
	Mangola Shoal	2	-	-	37.7	-	-
	Jabiru Shoals	2	1	-	26.8	28.5	-
	Pee Shoal	1	1	-	30.6	33.2	-
	Vee Shoal	2	1	-	29.3	35.8	-
	Newby Shoal	-	-	-	-	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	-	-	-	-	-	-
	Flat Top Bank	-	-	-	-	-	-
	Deep Shoal 1	-	-	-	-	-	-
	Johnson Bank	2	1	-	39.3	40.4	-
	Woodbine Bank	3	-	-	56.0	-	-
	Barracouta Shoal	1	-	-	43.9	-	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	-	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	1	1	-	50.8	51.9	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	-	-	-	-	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	-	-	-	-	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	-	-	-	-	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-

	Echuca Shoal	-	-	-	-	-	-
	Heritage Reef	-	-	-	-	-	-
	Camden Sound Marine Park	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	11	2	-	18.5	20.9	-
	East Timor	12	3	-	22.7	22.9	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	1	-	-	32.7	-	-
	Hibernia Reef	1	-	-	39.2	39.5	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
	Seringapatam Reef	-	-	-	-	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	-	-	-	-	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	27	13	3	0.8	0.8	1.1
	Oceanic CMR	76	28	3	0.3	0.3	1.4

	Arnhem Commonwealth Marine Reserve	-	-	-	-	-	-
	Ashmore Reef CMR	1	-	-	62.5	-	-
	Cartier Island CMR	-	-	-	-	-	-
	Kimberley CMR	-	-	-	-	-	-
	Joseph Bonaparte Gulf CCMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	22	9	-	15.3	20.8	-
	Shelf break and slope of the Arafura Shelf	65	29	8	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	31	7	1	1.4	1.4	1.5
	Pinnacles of the Bonaparte Basin	1	-	-	14.6		-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	68	38	14	0.04	0.04	0.04

Transitional conditions (March and September to November)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	55	14	-	5.7	6.6	-
	Loxton Shoal	56	16	-	4.4	4.8	-
	Martin Shoal	67	19	1	3.5	3.9	7.7
	Sunrise Bank	53	14	-	8.1	8.7	-
	Flinders Shoal	87	48	4	1.0	1.5	1.6
	Evans Shoal	97	63	12	0.1	0.1	0.3
	Tassie Shoal	89	46	7	0.1	0.1	0.8
	Franklin Shoal	91	59	6	0.6	0.6	1.3
	Blackwood Shoal	90	52	2	0.4	0.4	1.8
	Lynedoch Bank	19	8	-	1.4	2.0	-
	Margaret Harries Bank	75	29	2	2.5	2.9	8.3
	Bellona Bank	44	12	-	13.1	13.2	-
	Echo Shoals	28	6	-	14.8	14.9	-
	Money Shoal	3	1	-	33.0	33.8	-

	Troubadour Shoals	79	39	3	5.3	5.4	5.5
	Big Bank Shoals	23	5	-	19.4	19.7	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	23	4	-	17.3	21.5	-
	Cootamundra Shoal	11	3	-	8.7	8.8	-
	Calder Shoal	12	4	-	7.4	8.2	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	15	2	-	23.6	27.3	-
	Dillon Shoal	18	3	-	21.7	26.7	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	10	1	-	30.7	34.7	-
	The Boxers	2	2	-	16.6	16.6	-
	Fantome Shoal	2	-	-	41.9	-	-
	Mangola Shoal	3	-	-	34.2	-	-
	Jabiru Shoals	2	1	-	31.3	36.2	-
	Pee Shoal	2	1	-	31.4	36.7	-
	Vee Shoal	1	1	-	35.6	38.2	-
	Newby Shoal	-	-	-	-	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	1	-	-	30.5	-	-
	Flat Top Bank	-	-	-	-	-	-
	Deep Shoal 1	-	-	-	-	-	-
	Johnson Bank	2	-	-	39.8	-	-
	Woodbine Bank	3	-	-	37.4	-	-
	Barracouta Shoal	1	-	-	41.5	-	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	67.5	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	2	-	-	46.8	-	-

	Baldwin Bank	1	-	-	71.8	-	-
	Goeree Shoal	2	-	-	50.7	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	-	-	-	-	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	1	-	-	54.5	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	1	-	-	71.9	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	12	3	-	16.9	17.0	-
	East Timor	11	3	-	18.8	18.8	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	2	-	-	35.3	-	-
	Hibernia Reef	3	1	-	33.3	38.8	-
	Ashmore Reef	3	1	-	48.3	51.1	-
	Cartier Island	-	-	-	-	-	-
	Seringapatam Reef	-	-	-	-	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-

	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	-	-	-	-	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	8	3	-	18.5	19.8	-
	Oceanic Shoals CMR	67	26	3	0.6	0.6	0.8
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	3	-	-	33.2	-	-
	Cartier Island CMR	3	-	-	45.6	-	-
	Kimberley CMR	1	1	-	56.2	56.8	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	1	-	-	51.3	-	-
KEF	Tributary Canyons of the Arafura Depression	10	8	-	19.8	23.1	
	Shelf break and slope of the Arafura Shelf	41	18	9	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	39	7	1	0.1	0.1	0.2
	Pinnacles of the Bonaparte Basin	6	2	-	11.8	12.6	-
	Carbonate bank and terrace system of Sahul Shelf	8	2	-	24.3	24.6	-
	Continental slope demersal fish communities	1	-	-	30.0	-	-
Fishery	Timor Reef Fishery (NT Managed)	55	14	-	0.1	0.1	0.1

Winter conditions (April to August)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	77	20	1	4.4	5.0	8.6
	Loxton Shoal	82	22	1	3.9	4.0	7.7

	Martin Shoal	86	36	1	2.8	3.7	6.3
	Sunrise Bank	61	11	-	9.1	9.2	-
	Flinders Shoal	95	52	5	1.2	1.2	1.4
	Evans Shoal	99	74	10	0.1	0.9	0.9
	Tassie Shoal	92	43	2	0.9	0.9	1.0
	Franklin Shoal	97	60	4	1.2	1.2	3.2
	Blackwood Shoal	99	56	1	1.2	1.2	2.6
	Lynedoch Bank	17	2	-	7.5	8.9	-
	Margaret Harries Bank	71	24	1	5.6	6.2	7.4
	Bellona Bank	59	9	-	10.4	13.6	-
	Echo Shoals	56	7	-	12.3	13.5	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	91	37	1	5.1	5.5	9.3
	Big Bank Shoals	37	4	-	15.2	15.5	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	46	8	1	14.5	17.2	22.9
	Cootamundra Shoal	7	4	-	18.7	19.5	-
	Calder Shoal	9	1	-	7.8	8.7	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	32	4	1	16.3	21.1	26.7
	Dillon Shoal	37	3	-	16.9	21.0	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	16	2	-	20.1	25.8	-
	The Boxers	5	1	-	19.9	23.3	-
	Fantome Shoal	6	-	-	28.3	-	-
	Mangola Shoal	4	1	-	35.4	40.3	-
	Jabiru Shoals	4	1	-	33.7	44.6	-
	Pee Shoal	4	1	-	27.7	39.9	-
	Vee Shoal	3	1	-	37.0	47.4	-

	Newby Shoal	1	-	-	45.2	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	2	-	-	40.3	-	-
	Flat Top Bank	2	-	-	45.9	-	-
	Deep Shoal 1	4	1	-	42.8	55.5	-
	Johnson Bank	1	-	-	48.3	-	-
	Woodbine Bank	1	-	-	48.8	-	-
	Barracouta Shoal	-	-	-	-	-	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	61.3	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	-	-	-	-	-	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	-	-	-	-	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	1	-	-	73.0	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	-	-	-	-	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	-	-	-	-	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	8	2	-	15.3	24.4	-
	East Timor	10	1	-	18.6	27.8	-

Emergent receptor	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	1	-	-	42.0	-	-
	Ashmore Reef	2	-	-	41.0	51.5	-
	Cartier Island	1	-	-	54.9	-	-
	Seringapatam Reef	-	-	-	-	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	-	-	-	-	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	52	21	2	1.7	1.7	3.4
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	2	1	-	38.1	51.5	-
	Cartier Island CMR	1	-	-	53.9	-	-
	Kimberley CMR	-	-	-	-	-	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-

	Shelf break and slope of the Arafura Shelf	42	15	9	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	32	12	1	0.2	0.2	0.2
	Pinnacles of the Bonaparte Basin	50	18	1	8.4	8.4	9.7
	Carbonate bank and terrace system of Sahul Shelf	7	2	1	23.3	24.1	34.1
	Continental slope demersal fish communities	7	1	-	31.0	40.4	-
Fishery	Timor Reef Fishery (NT Managed)	41	12	6	0.04	0.04	0.04

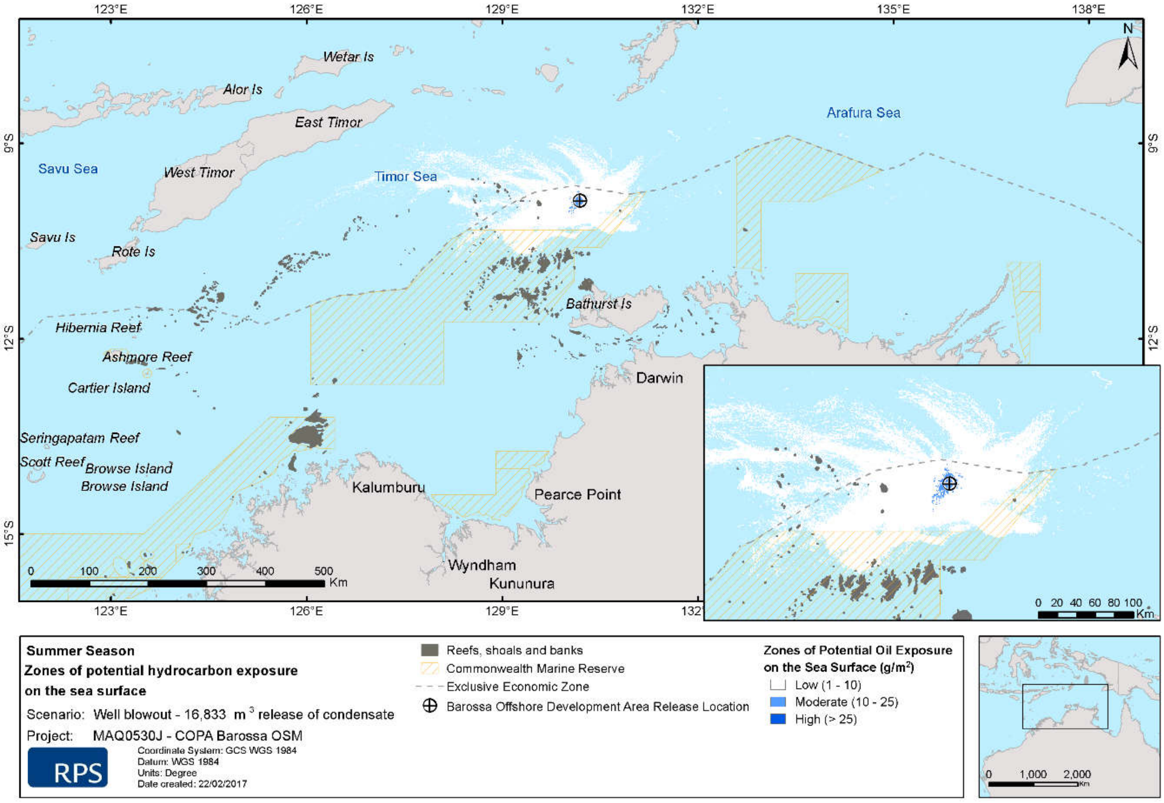


Figure 81 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (16,833 m^3 Barossa condensate)

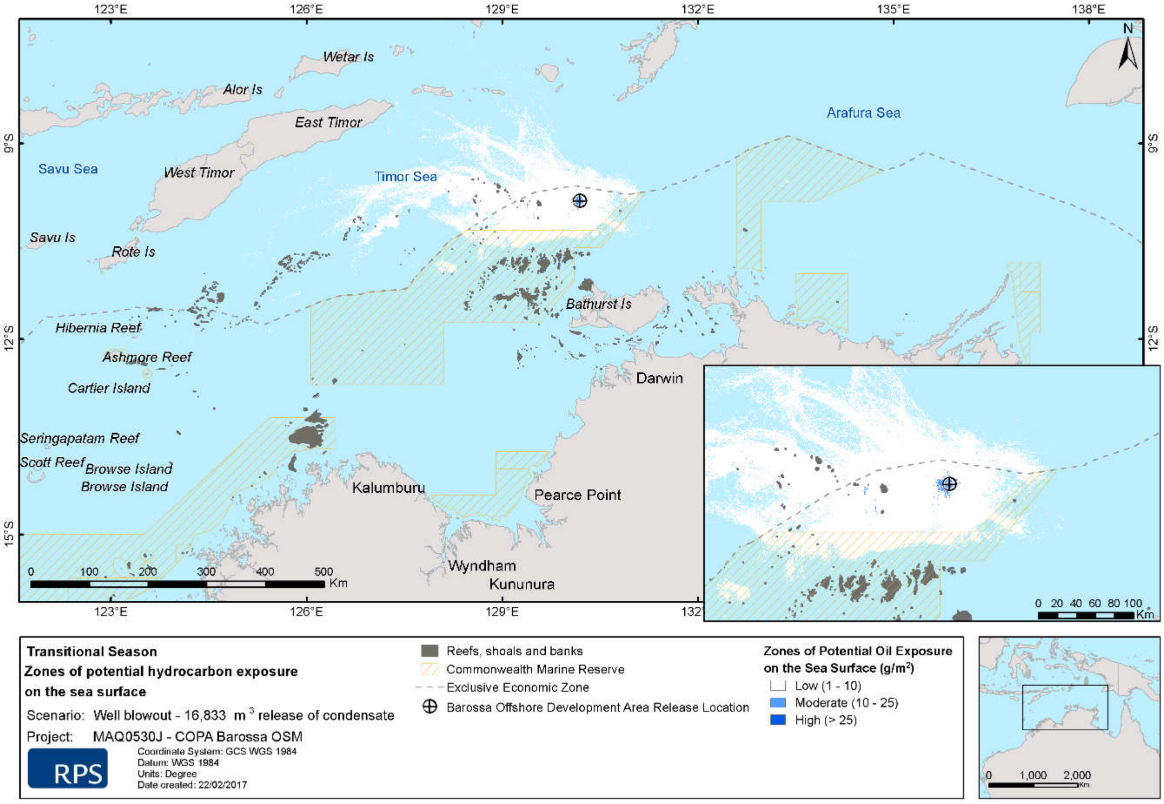


Figure 82 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (16,833 m^3 Barossa condensate)

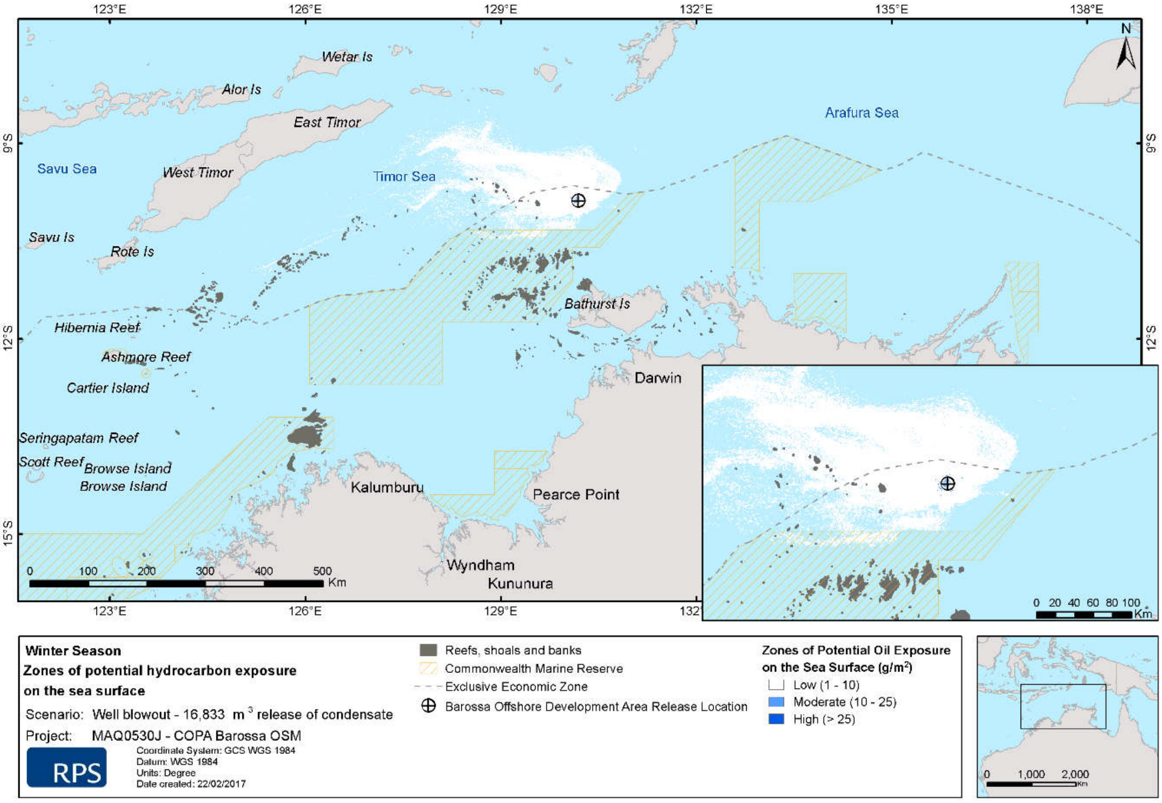


Figure 83 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (16,833 m^3 Barossa condensate)

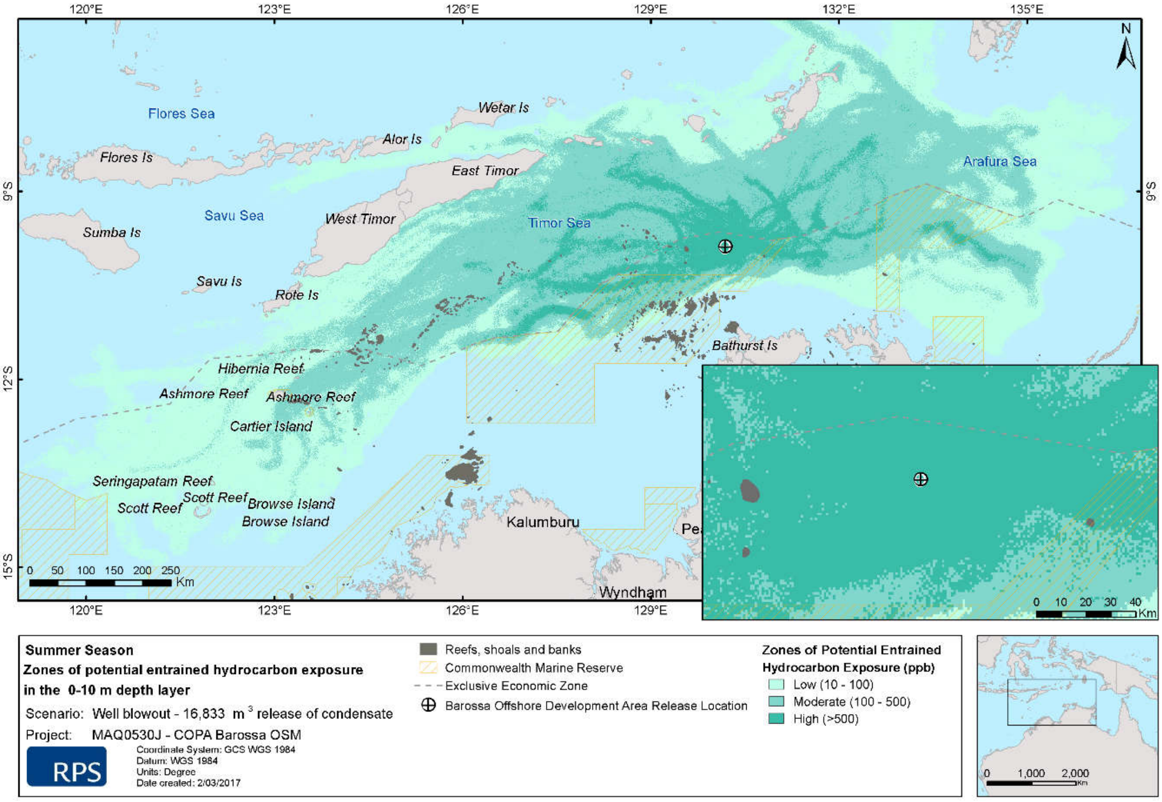


Figure 84 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (16,833 m^3 Barossa condensate)

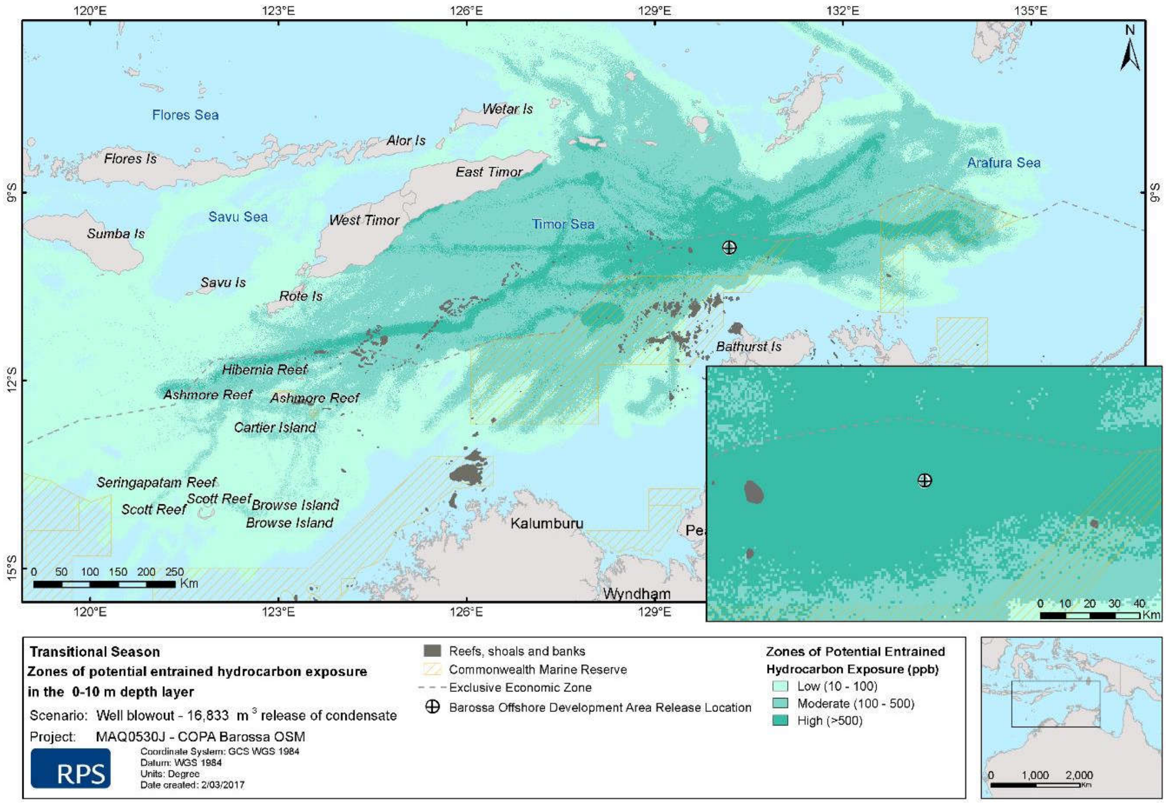


Figure 85 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (16,833 m^3 Barossa condensate)

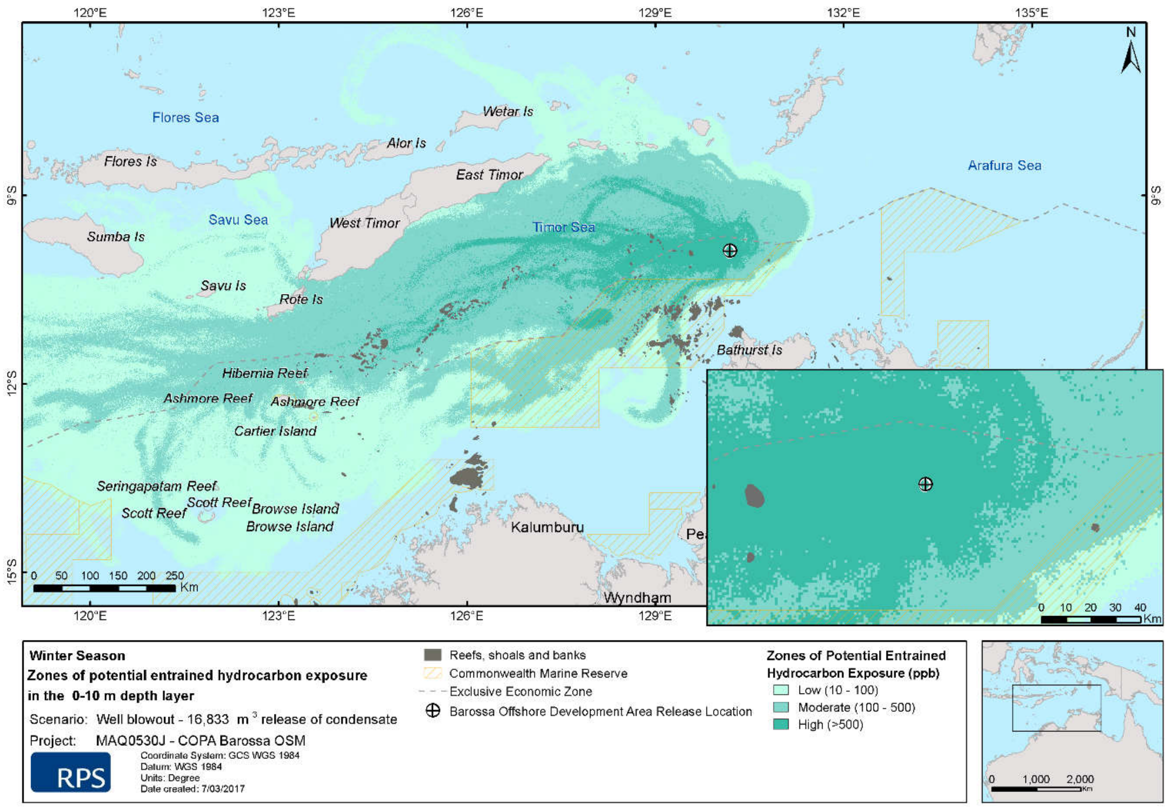


Figure 86 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (16,833 m^3 Barossa condensate)

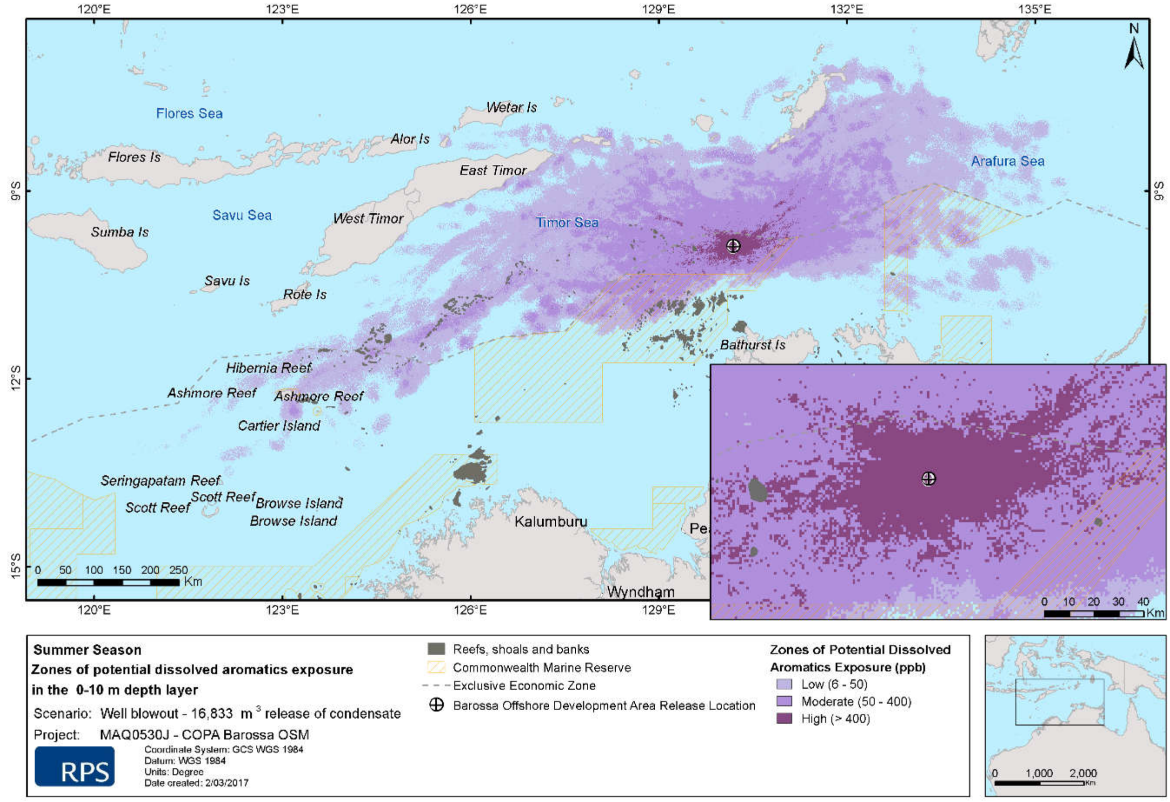


Figure 87 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (16,833 m^3 Barossa condensate)

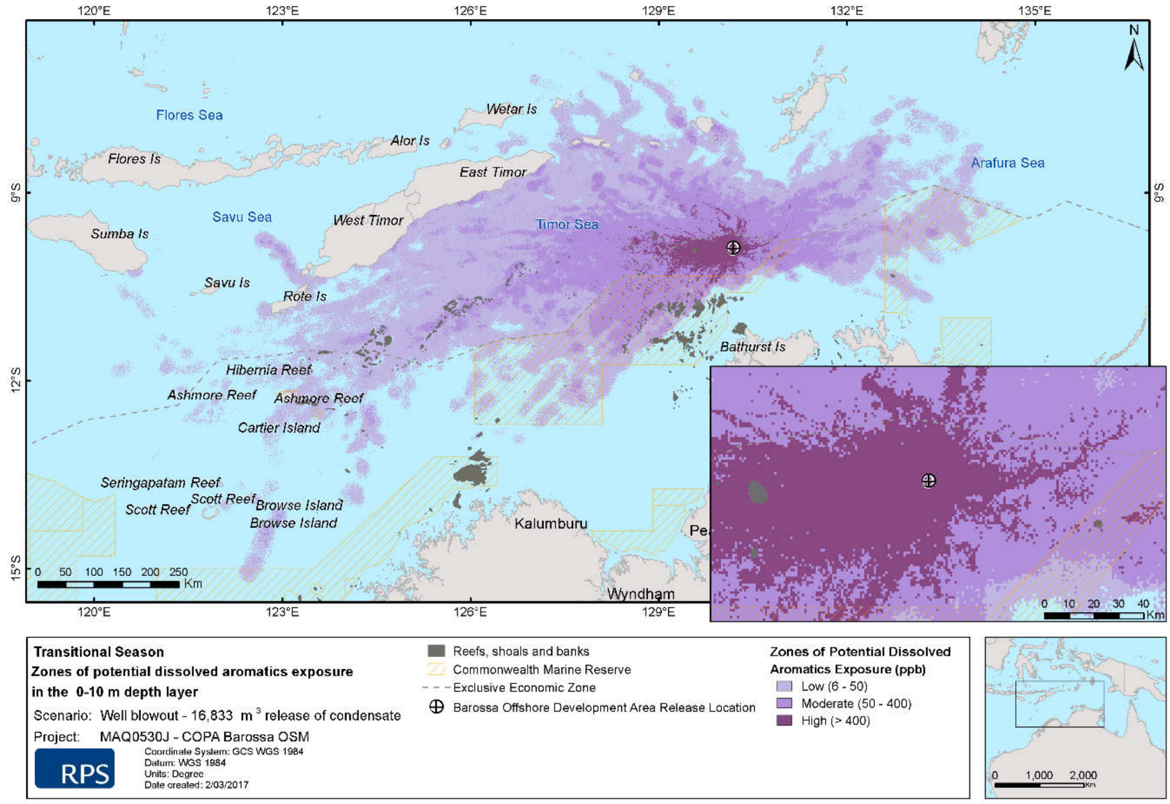


Figure 88 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (16,833 m^3 Barossa condensate)

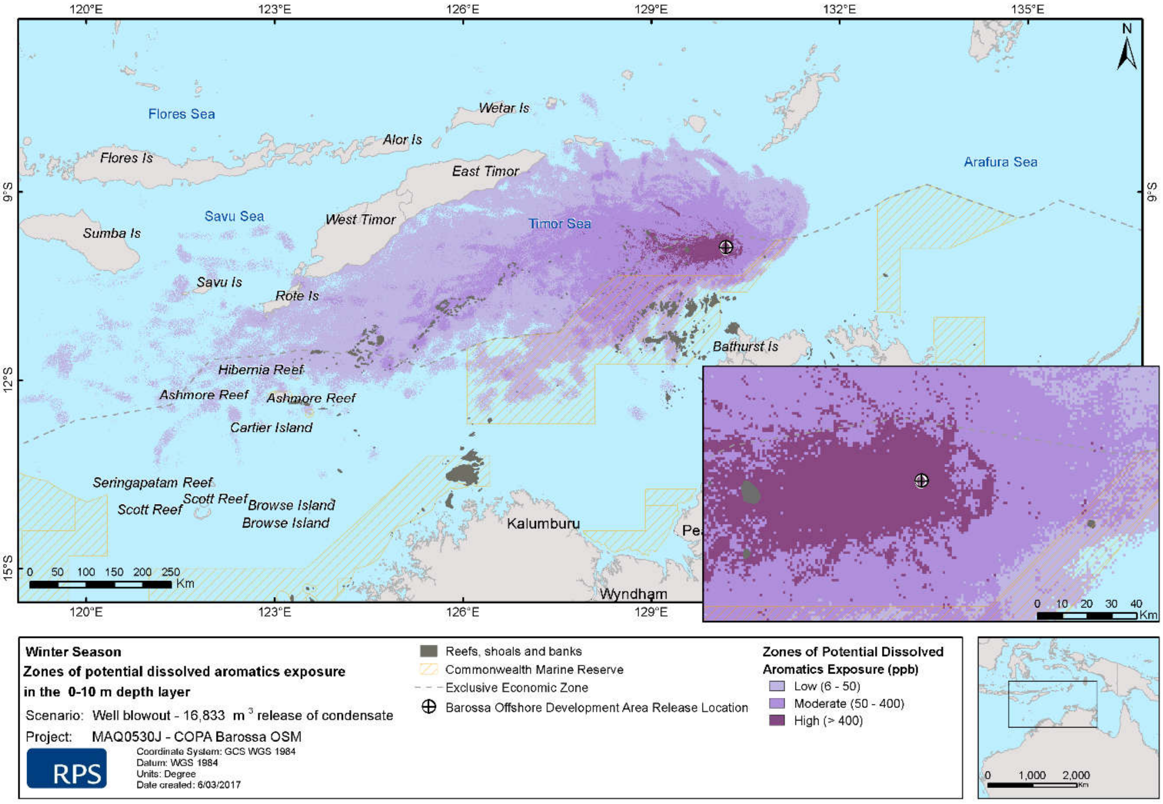


Figure 89 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (16,833 m^3 Barossa condensate)

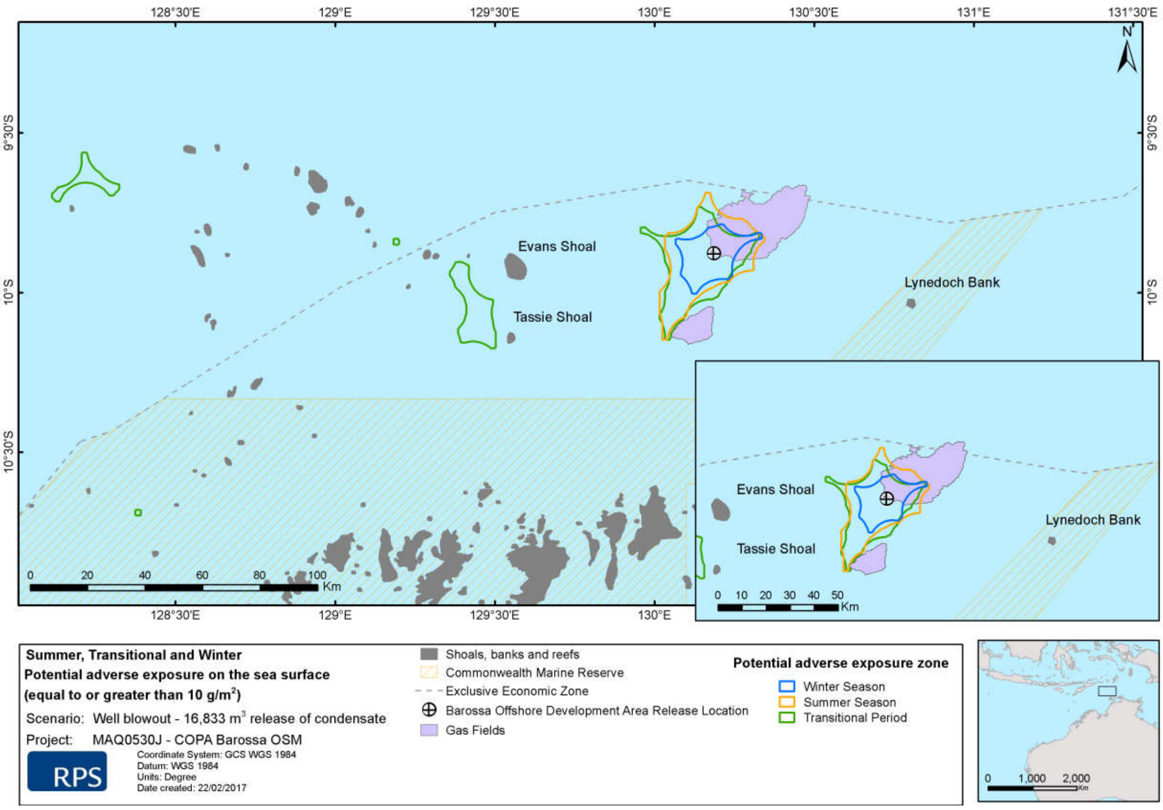


Figure 90 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a long-term well blowout of Barossa condensate (16,833 m^3)

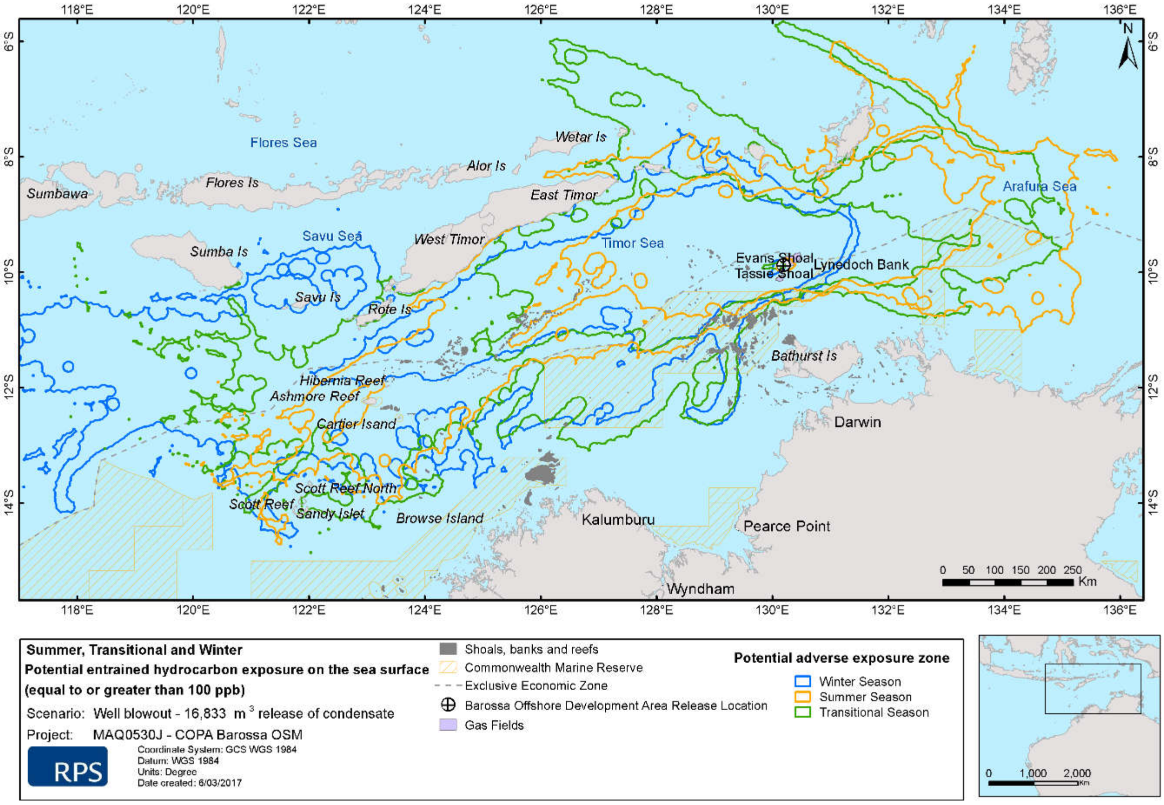


Figure 91 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for entrained hydrocarbons from a long-term well blowout of Barossa condensate (16,833 m^3)

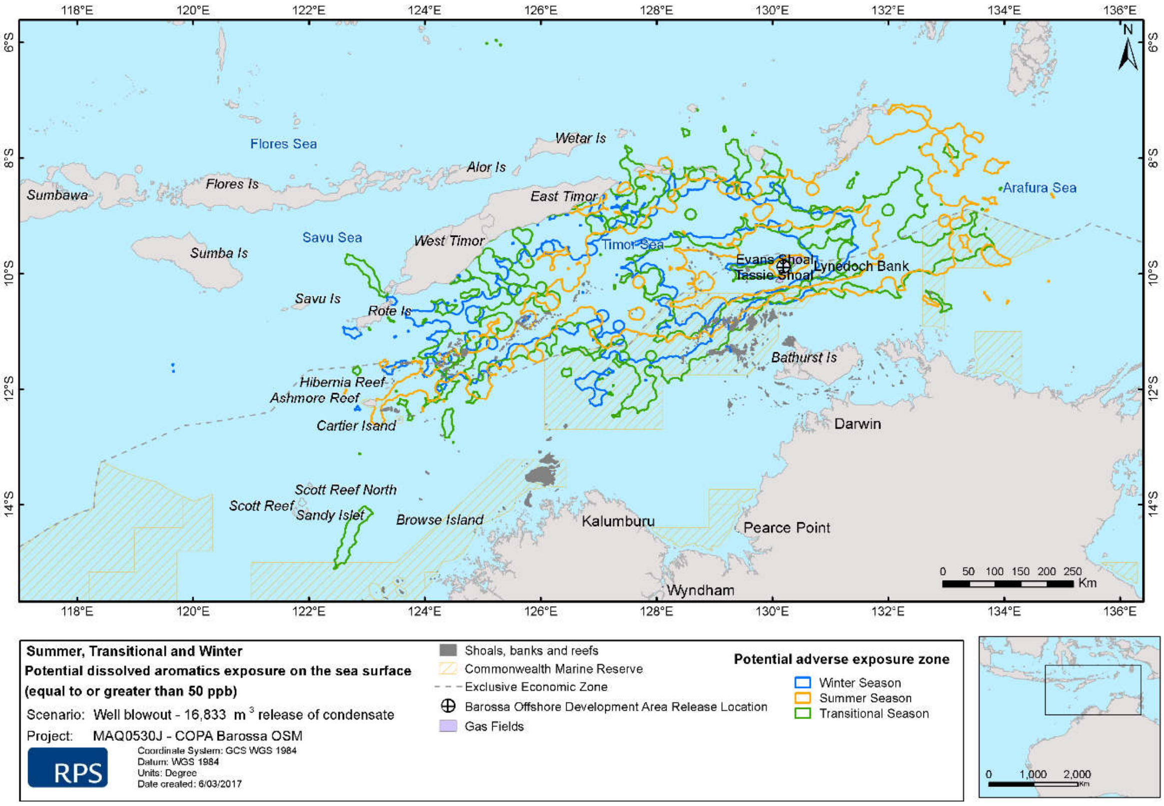


Figure 92 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for dissolved aromatics hydrocarbons from a long-term well blowout of Barossa condensate (16,833 m^3)

3.5 Scenario 5: Vessel collision leading to loss of a single export tanker fuel tank (650 m^3 HFO)

3.5.1 Single trajectory

Figure 93 shows the potential sea surface hydrocarbon exposure zones over the entire 40 day model simulation. The spill starting at 9 am 21st April 2014 was used an example trajectory to illustrate the potential shoreline exposure to East Timor during the winter season.

The hydrocarbon travelled northwest toward East Timor upon release. The adverse exposure zone (high and moderate exposure) was observed up to 45 km and 115 km, respectively, from the release location. There was no entrained or dissolved aromatic hydrocarbons was predicted within the adverse exposure zone.

Figure 94 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that evaporation only occurred over the first 24 hours. The hydrocarbon reached the shoreline 16 days after the release. At the end of the simulation (day 40) approximately 9% (56 m^3) had evaporated and 64% (418 m^3) had decayed.

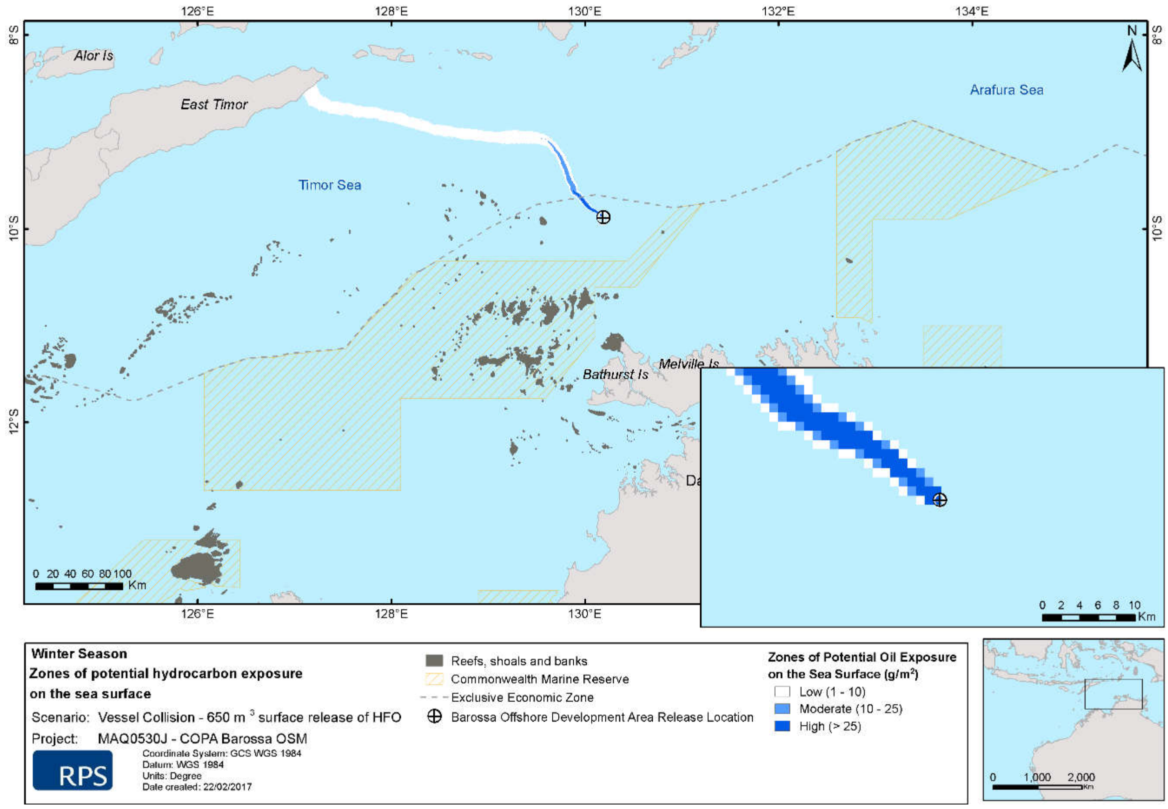


Figure 93 Single spill trajectory outputs showing the potential sea surface exposure zones (650 m^3 HFO)

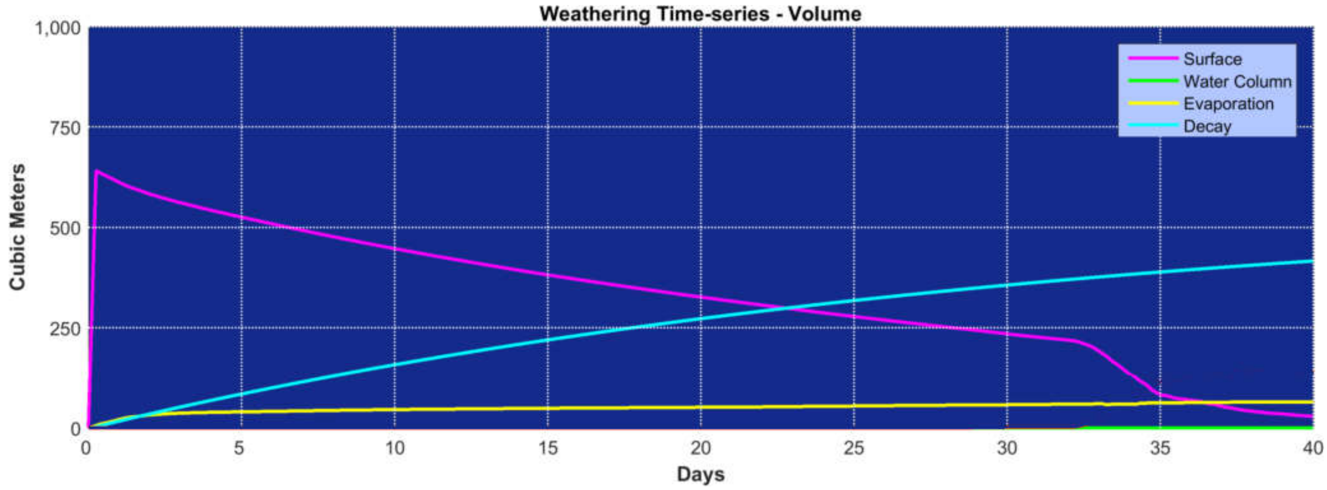


Figure 94 Predicted weathering and fates graph for the example spill trajectory from a 650 m³ surface release of HFO from a single export tanker fuel tank rupture (tracked for 40 days)

3.5.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, the released hydrocarbons tended to initially travel east of the release location before travelling in variable directions, whereas during the transitional and winter seasons hydrocarbons were more prone to drift west.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 393 km, 277 km and 805 km during summer, transitional and winter conditions, respectively (Table 31**)**.
- contact was predicted (1–17% probability) by sea surface films within the adverse exposure zone to surface waters above a number of submerged shoals/banks (total of 13), KEFs of the carbonate bank and terrace system of Van Diemen Rise, tributary canyons of the Arafura Depression and the open waters of the Oceanic Shoals and Arafura CMRs, depending on the season (Table 32).
- Figure 95 to Figure 97 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 98 shows the potential sea surface adverse exposure zone for all seasons.
- during summer conditions, the surface waters above Evans and Tassie Shoal recorded the highest probability of contact with the sea surface adverse exposure zone (1%) while during transitional and winter conditions the waters above Evans Shoal was predicted to have the highest probability of contact with the sea surface adverse exposure zone (17% and 13% respectively).
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa development area is located within the bounds of these features (Table 32).
- no shoreline contact or contact by entrained or dissolved aromatic hydrocarbons was predicted within the adverse exposure zone during any season.

Table 31 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (650 m³ HFO)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	839.6	393.4	111.2
	Direction	East	East	East-southeast
Transitional	Maximum distance travelled (km) by a spill trajectory	799.3	277.1	243.5
	Direction	West-southwest	West	West
Winter	Maximum distance travelled (km) by a spill trajectory	1089.6	805.5	789.5
	Direction	West	West-southwest	West-southwest

Table 32 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (650 m^3 HFO)

Summer conditions (December to February)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	-	-	-	0.0	-	-
	Loxton Shoal	1	-	-	17.5	-	-
	Martin Shoal	2	-	-	10.5	-	-
	Sunrise Bank	1	-	-	12.8	-	-
	Troubadour Shoals	1	-	-	8.0	-	-
	Flinders Shoal	2	-	-	10.6	-	-
	Evans Shoal	9	1	-	2.5	2.7	-
	Tassie Shoal	11	1	-	6.4	7.3	-
	Franklin Shoal	2	-	-	10.4	-	-
	Blackwood Shoal	4	-	-	10.3	-	-
	Lynedoch Bank	11	-	-	2.4	-	-
	Margaret Harries Bank	2	-	-	28.3	-	-
	Bellona Bank	1	-	-	34.7	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	5	-	-	11.1	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	7	-	-	13.8	-	-
	Calder Shoal	7	-	-	13.8	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	69	6	-	8.2	9.2	-
	Oceanic Shoals CMR	81	49	6	1.5	1.5	1.8

	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	29	3	-	10.3	11.5	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	25	15	4	2.4	2.7	5.0
	Pinnacles of the Bonaparte Basin	2	-	-	29.8	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		**Maximum probability of hydrocarbon exposure on the sea surface (%)**			**Minimum time before receptor exposed to hydrocarbons on the sea surface (days)**		
		Low (1–10 g/m²)	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**	**Low (1–10 g/m²)**	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**
Submerged receptor	Sunset Shoal	13	-	-	6.5	-	-
	Loxton Shoal	10	1	-	5.9	7.5	-
	Martin Shoal	9	-	-	5.6	-	-
	Sunrise Bank	10	-	-	8.1	-	-
	Troubadour Shoals	32	4	-	6.3	6.4	-
	Flinders Shoal	27	9	1	3.5	3.7	3.8
	Evans Shoal	39	17	1	2.3	2.5	2.9
	Tassie Shoal	7	4	-	3.2	3.3	-
	Franklin Shoal	29	6	-	3.5	3.7	-
	Blackwood Shoal	29	2	-	3.0	3.4	-
	Lynedoch Bank	7	1	-	2.8	4.2	-
	Margaret Harries Bank	14	1	-	7.5	9.0	-
	Bellona Bank	8	-	-	16.8	-	-
	Echo Shoals	18	-	-	15.7	-	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	2	-	-	27.1	-	-
	Karmt Shoal	7	-	-	23.4	-	-
	Cootamundra Shoal	4	-	-	19.8	-	-
	Calder Shoal	-	-	-	-	-	-

	Sahul Bank	8	-	-	24.3	-	-
	Dillon Shoal	2	-	-	25.2	-	-
Emergent receptor	Indonesia	1	-	-	33.2	-	-
	East Timor	3	-	-	33.6	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	1	-	-	11.5	-	-
	Oceanic Shoals CMR	31	9	-	2.4	2.5	-
	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	32	26	5	2.6	2.7	3.1
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Winter conditions (April to August)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	16	2	-	5.1	5.2	-
	Loxton Shoal	15	2	-	4.6	4.7	-
	Martin Shoal	18	2	-	3.5	4.2	-
	Sunrise Bank	2	-	-	9.3	-	-
	Troubadour Shoals	14	3	-	4.8	4.9	-
	Flinders Shoal	16	6	-	2.8	3.6	-
	Evans Shoal	27	13	2	1.8	2.1	2.8
	Tassie Shoal	3	1	-	4.0	4.5	-
	Franklin Shoal	14	6	-	2.8	2.8	-
	Blackwood Shoal	17	5	-	2.1	2.2	-
	Lynedoch Bank	1	-	-	5.1	-	-
	Margaret Harries Bank	7	-	-	6.5	-	-

	Bellona Bank	5	-	-	11.1	-	-
	Echo Shoals	14	2	-	10.1	11.9	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	4	-	-	14.7	-	-
	Karmt Shoal	6	-	-	14.5	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	9	1	-	17.0	31.6	-
	Dillon Shoal	2	-	-	19.6	-	-
Emergent receptor	Indonesia	31	-	-	14.4	-	-
	East Timor	22	-	-	15.0	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	5	1	-	4.5	9.8	-
	Ashmore Reef CMR	1	-	-	33.7	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	26	15	5	1.5	1.6	2.9
	Pinnacles of the Bonaparte Basin	1	-	-	14.3	-	-
	Continental slope demersal fish communities	1	-	-	31.9	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

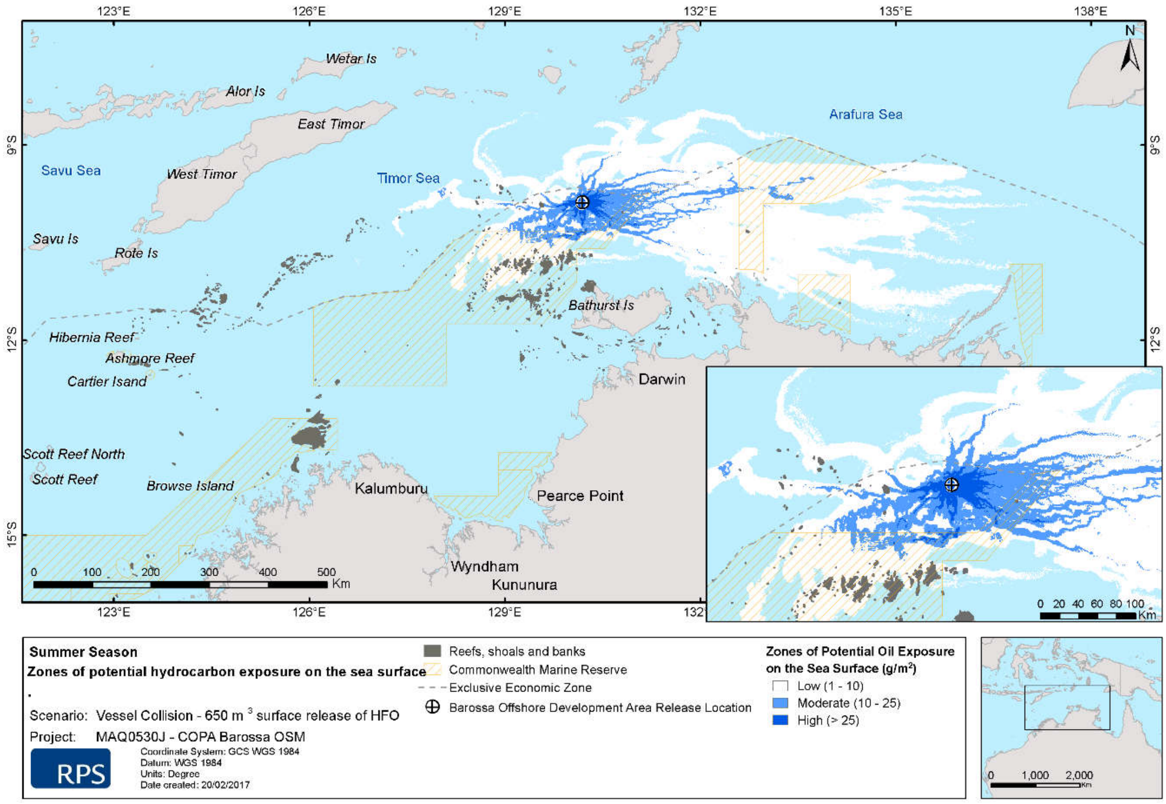


Figure 95 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (650 m³ HFO)

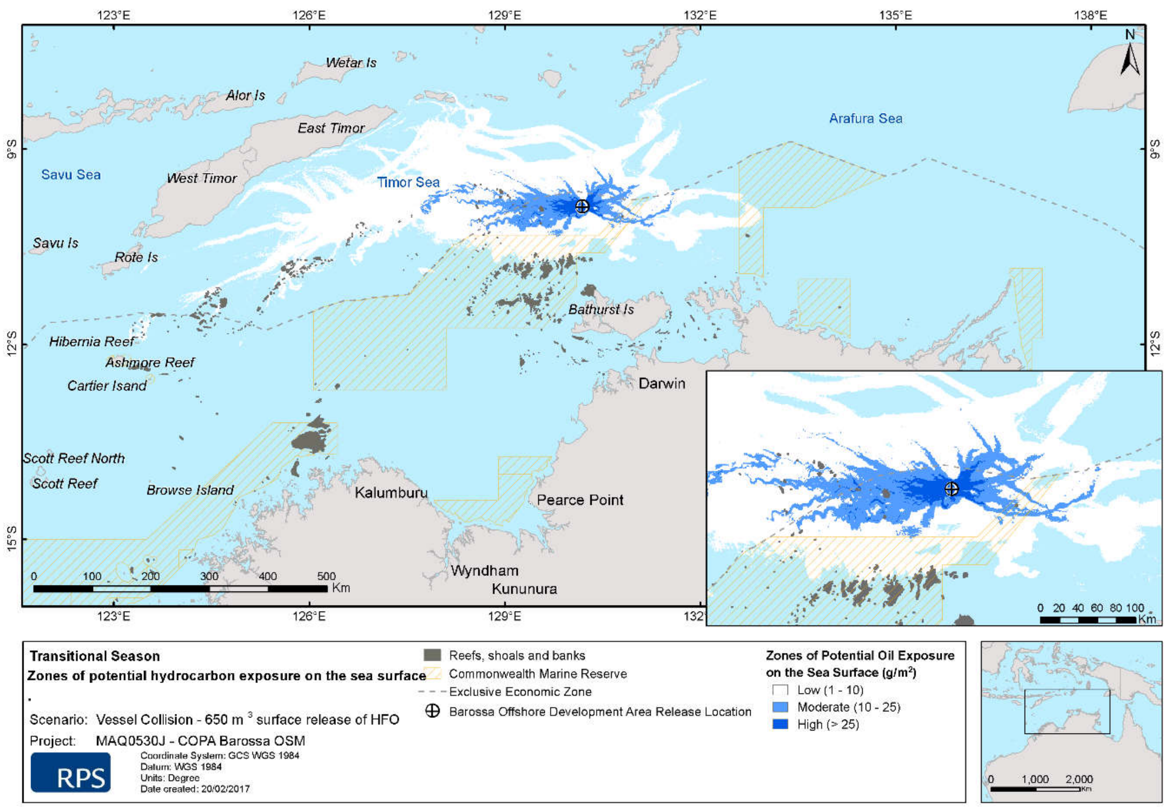


Figure 96 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (650 m³ HFO)

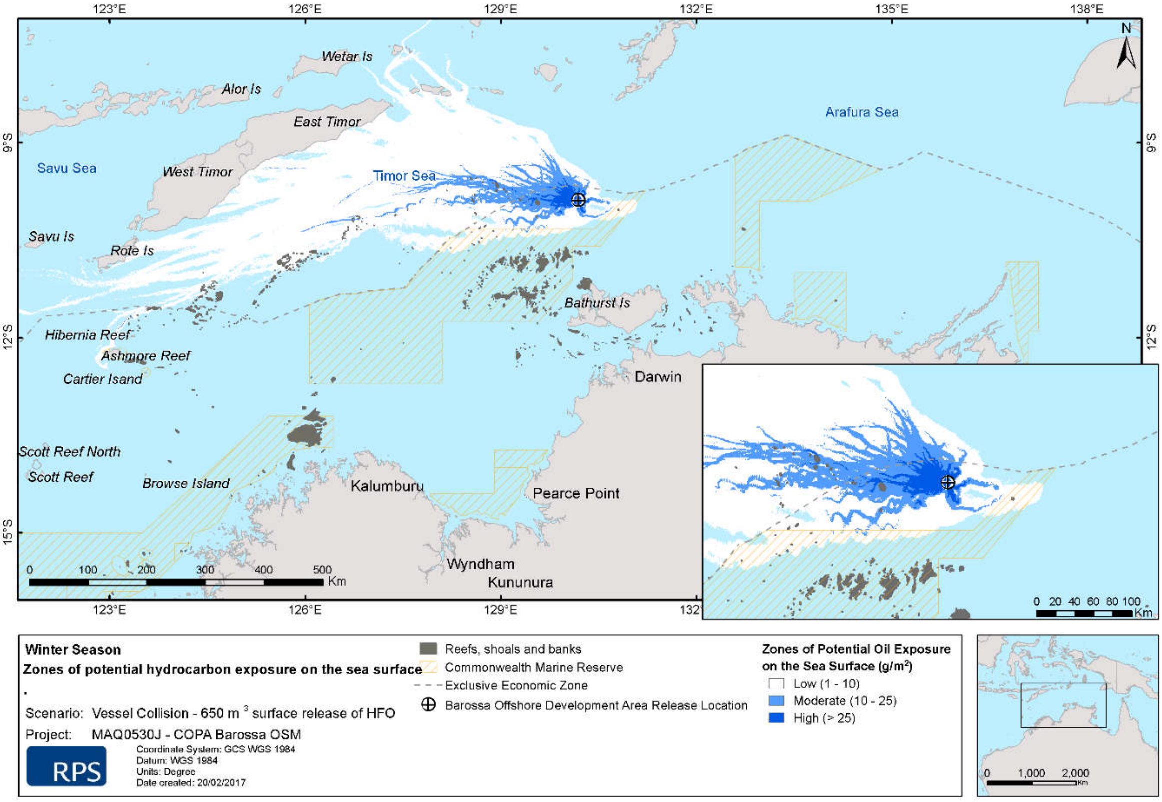


Figure 97 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (650 m^3 HFO)

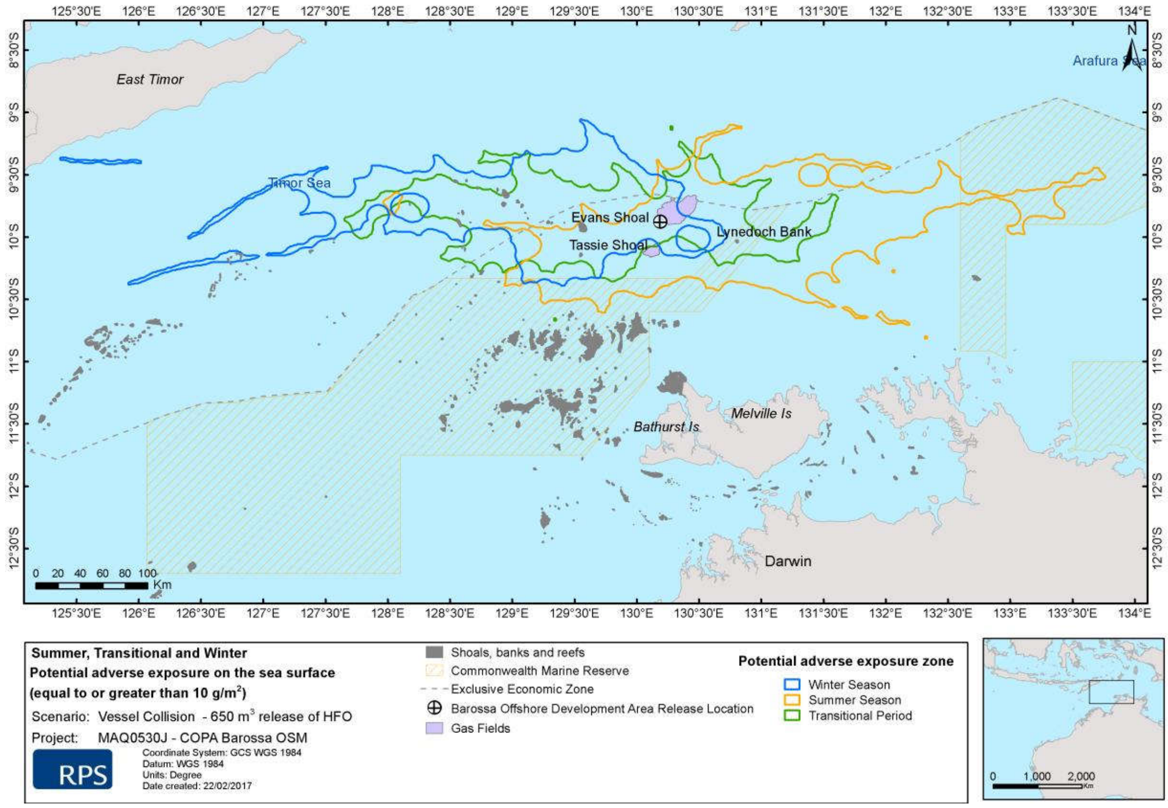


Figure 98 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a vessel collision releasing HFO (650 m^3)

3.6 Scenario 6: Vessel collision leading to loss of a single pipelay vessel fuel tank (500 m^3 IFO-180)

3.6.1 Single trajectory

Figure 99 shows the predicted sea surface hydrocarbon exposure zones over the entire 40 day model simulation. The spill starting at 8 am 24th January 2014 was selected as an example as the hydrocarbon was predicted to travel towards the closest shoreline of Bathurst Island during the summer season.

The hydrocarbon travelled east toward Bathurst Island upon release. The adverse exposure zone (high and moderate exposure) was observed up to 18 km and 79 km, respectively, from the release location.

There was no entrained or dissolved aromatic hydrocarbon exposure is predicted at any threshold; consequently, no subsea images are presented for this scenario.

Figure 100 illustrates the fates and weathering graph for the corresponding summer spill trajectory. The graph demonstrates a higher rate of evaporation over the first 48 hours comparative to the remaining simulation period. The hydrocarbon reached the shoreline 24 hours after the release. At the end of the simulation (day 40) approximately 19% (95 m^3) had evaporated and 57% (287 m^3) had decayed.

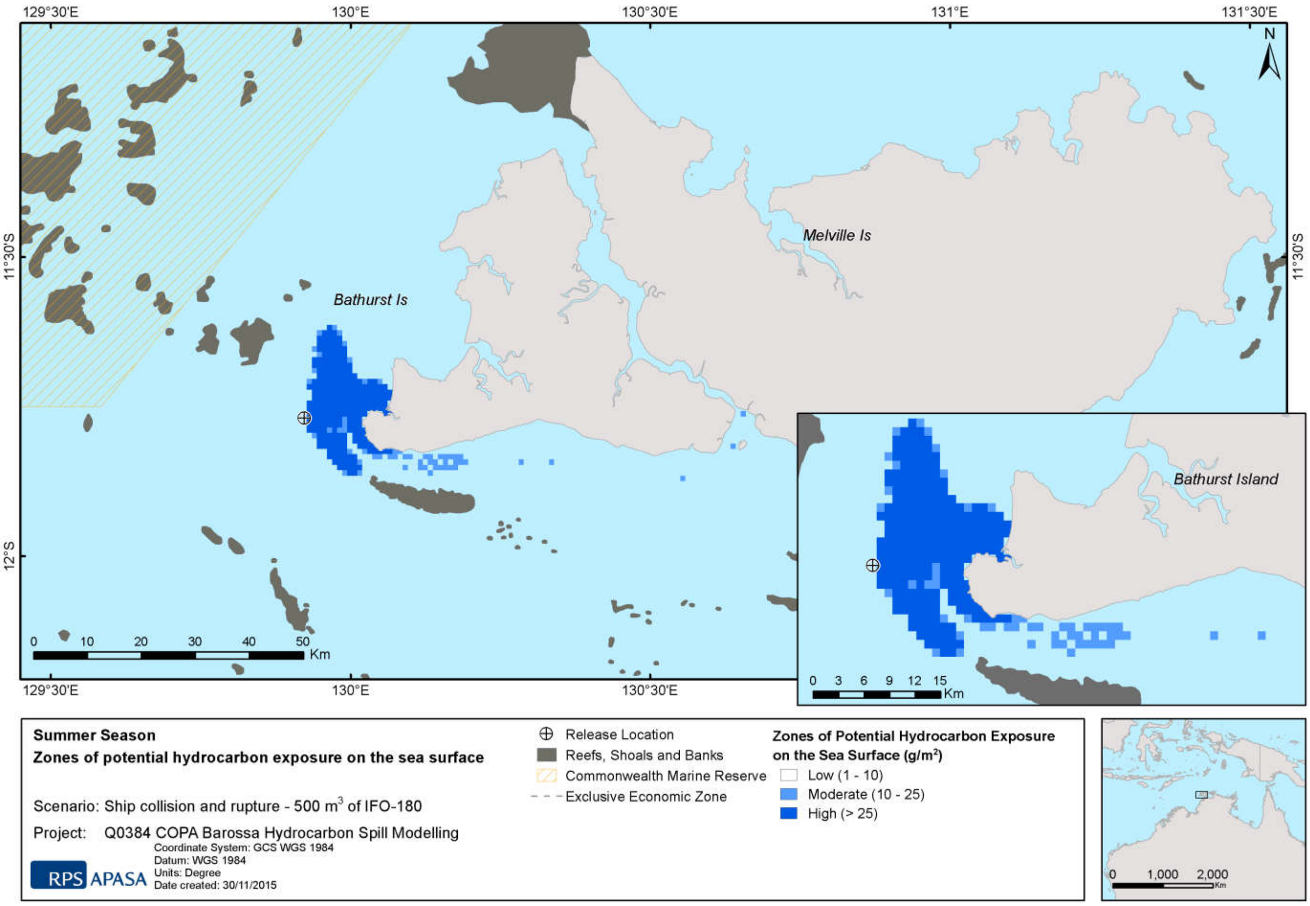


Figure 99 Single spill trajectory outputs showing the potential sea surface exposure zones (500 m^3 IFO-180)

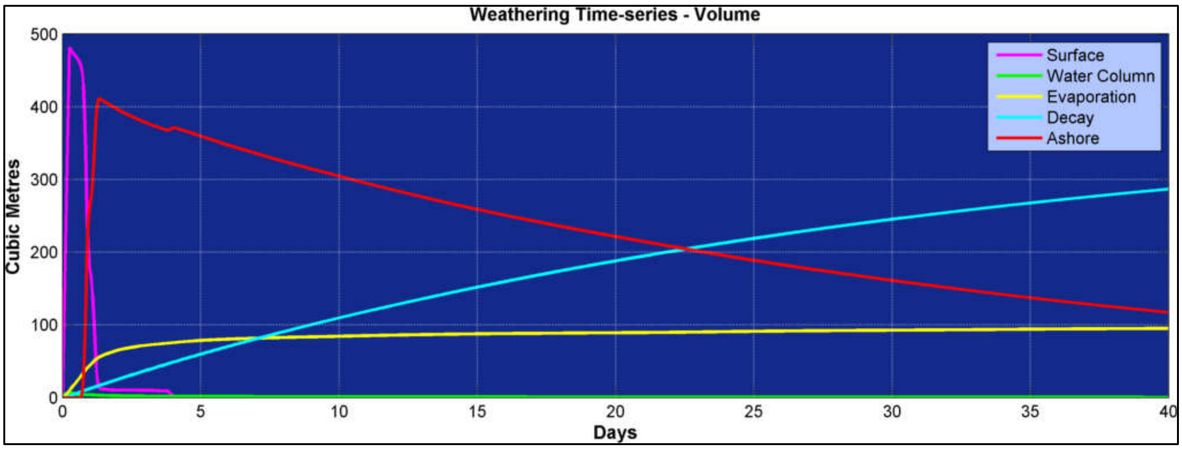


Figure 100 Predicted weathering and fates graph for the example spill trajectory from a 500 m^3 surface release of IFO-180 from a ship collision and rupture (tracked for 40 days)

3.6.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during the summer and transitional seasons, the hydrocarbon travelled east toward Bathurst Island. In winter, the hydrocarbon was more likely to travel offshore at much greater distances on the sea surface as it was unimpeded by contact with emergent features.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 136 km, 120 km and 395 km during summer, transitional and winter conditions, respectively (Table 33).
- low probability of contact predicted (1–16%) by sea surface films within the adverse exposure zone with the surface waters above three submerged shoals/banks and reefs and KEF of the carbonate bank and terrace system of Van Diemen Rise (40–70% probability), and the open waters of the Oceanic Shoals CMR, depending on the season (Table 34). Figure 101 to Figure 103 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 104 shows the potential sea surface adverse exposure zone for all seasons.
- during summer and transitional conditions, the surface waters above Afghan Shoal recorded the highest probability of contact with the sea surface adverse exposure zone (16% and 14% respectively). During winter conditions, only the waters above Shepparton Shoal were predicted to be contacted by the sea surface adverse exposure zone (4%).
- contact was predicted (1–34% probability) by sea surface films within the adverse exposure zone with Bathurst Island, Melville Island and the Darwin coastline in the summer and transitional seasons only (Table 34).
- no entrained or dissolved aromatic hydrocarbon exposure is predicted at any threshold in any season and therefore no contact with submerged or in-water receptors is expected through this exposure pathway.

Table 33 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (500 m^3 IFO-180)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	305.2	135.7	41.4
	Direction	East	East-southeast	Southeast
Transitional	Maximum distance travelled (km) by a spill trajectory	402.4	120.0	39.9
	Direction	West	Southeast	Southeast
Winter	Maximum distance travelled (km) by a spill trajectory	964.4	395.0	58.6
	Direction	West	West-northwest	Northwest

Table 34 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (500 m³ IFO-180)

Summer conditions (December to February)								
Receptors		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Mermaid Shoal	4	-	-	7.9	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	1	-	-	7.8	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Mataram Shoal	-	-	-	-	-	-
	Renard Shoals	1	-	-	16.1	-	-
	Giles Shoal	1	-	-	16.8	-	-
	Christine Shoal	1	-	-	18.4	-	-
	Margaret Shoal	1	-	-	19.5	-	-
	Wells Shoal	2	-	-	9.6	-	-
	Beagle Shoals	1	-	-	15.5	-	-
	Taiyun Shoal	2	-	-	6.5	-	-
	Hunt Patch	2	-	-	8.2	-	-
	Abbott Shoal	1	-	-	16.5	-	-
	Beatrice Reef	1	-	-	20.0	-	-
	Newby Shoal	-	-	-	-	-	-
	Barbara Shoal	1	-	-	17.0	-	-
	Afghan Shoal	48	16	5	0.1	0.1	0.3

	Bill Shoal	-	-	-	-	-	-
	Parsons Bank	2	-	-	2.9	-	-
	Taylor Patches	3	-	-	5.8	-	-
	Shepparton Shoal	15	2	-	1.0	1.0	-
	Tregenna Reef	3	-	-	5.8	-	-
	Harris Reef	7	-	-	3.3	-	-
	Moresby Shoals	13	-	-	3.2	-	-
	Knight Reef	8	-	-	4.3	-	-
	Hancox Shoal	12	-	-	3.5	-	-
	Oliver Reef	12	-	-	3.9	-	-
	Elizabeth Reef	2	-	-	8.3	-	-
	Draytons Reef	2	-	-	6.7	-	-
	Lowry Shoal	6	-	-	3.4	-	-
	Skottowe Shoal	11	-	-	2.3	-	-
	Flat Top Bank	3	-	-	8.5	-	-
	Marsh Shoal	15	-	-	3.9	-	-
	Lyne Reef	12	-	-	3.7	-	-
	Foelsche Bank	9	-	-	3.6	-	-
	Fish Reef	1	-	-	7.8	-	-
	Middle Reef	1	-	-	14.1	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	Melville Island	6	1	-	3.0	3.4	-
	Bathurst Island	55	34	11	0.3	0.4	0.5
	West Arnhem Land	1	-	-	17.8	-	-
	North West Vernon Island	17	-	-	2.9	-	-
	Kakadu Coast	7	-	-	3.3	-	-
	East Vernon Island	12	-	-	3.7	-	-
	Kakadu National Park	1	-	-	15.0	-	-
	South West Vernon Island	17	-	-	2.8	-	-
	Darwin Coast	8	2	-	2.8	6.3	-
	Joseph Bonaparte Gulf - Northern Territory	4	-	-	8.3	-	-

	Roche Islands and Reefs	4	-	-	7.7	-	-
	Peron Islands	1	-	-	24.0	-	-
CMR	Oceanic Shoals CMR	5	2	-	2.2	4.5	-
	Joseph Bonaparte Gulf CMR	1	-	-	33.5	-	-
KEF	Carbonate bank and terrace system of Van Diemen Rise	59	40	28	0.04	0.04	0.04
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	-	-	-	-	-	-

Transitional conditions (March and September to November)							
Receptors		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Marie Shoal	1	-	-	26.1	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal		-	-	-	-	-
	Mermaid Shoal	3	-	-	5.1	-	-
	Parry Shoal	1	-	-	22.7	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	1	-	-	23.6	-	-
	Mataram Shoal	1	-	-	10.3	-	-
	Renard Shoals	1	-	-	7.3	-	-
	Giles Shoal	1	-	-	11.7	-	-
	Christine Shoal	-	-	-	-	-	-
	Margaret Shoal	-	-	-	-	-	-
	Wells Shoal	1	-	-	10.8	-	-
	Beagle Shoals	1	-	-	7.1	-	-

	Taiyun Shoal	1	-	-	7.2	-	-
	Hunt Patch	1	-	-	6.3	-	-
	Abbott Shoal	1	-	-	9.6	-	-
	Beatrice Reef	-	-	-	-	-	-
	Newby Shoal	2	-	-	11.7	-	-
	Barbara Shoal	-	-	-	-	-	-
	Afghan Shoal	31	14	2	0.2	0.3	0.7
	Bill Shoal	1	-	-	8.2	-	-
	Parsons Bank	1	-	-	6.9	-	-
	Taylor Patches	1	-	-	7.8	-	-
	Shepparton Shoal	45	5	-	1.3	1.3	-
	Tregenna Reef	-	-	-	-	-	-
	Harris Reef	3	-	-	5.3	-	-
	Moresby Shoals	7	-	-	4.9	-	-
	Knight Reef	4	-	-	5.6	-	-
	Hancox Shoal	6	-	-	5.0	-	-
	Oliver Reef	4	-	-	5.1	-	-
	Elizabeth Reef	-	-	-	-	-	-
	Draytons Reef	1	-	-	7.9	-	-
	Lowry Shoal	5	-	-	4.5	-	-
	Skottowe Shoal	6	-	-	4.4	-	-
	Flat Top Bank	15	-	-	3.5	-	-
	Marsh Shoal	3	-	-	5.5	-	-
	Lyne Reef	3	-	-	5.8	-	-
	Foelsche Bank	1	-	-	13.3	-	-
	Fish Reef	2	-	-	12.5	-	-
	Middle Reef	2	1	-	12.4	13.1	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	Melville Island	4	1	-	4.5	7.9	-
	Bathurst Island	28	12	1	0.6	0.6	0.8
	West Arnhem Land	-	-	-	-	-	-

	North West Vernon Island	7	-	-	5.1	-	-
	Kakadu Coast	3	-	-	6.6	-	-
	East Vernon Island	7	-	-	5.6	-	-
	Kakadu National Park	-	-	-	-	-	-
	South West Vernon Island	7	-	-	5.5	-	-
	Darwin Coast	3	1	-	4.3	5.8	-
	Joseph Bonaparte Gulf - Northern Territory	3	-	-	4.6	-	-
	Roche Islands and Reefs	4	-	-	12.8	-	-
	Peron Islands	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	10	2	-	0.8	1.8	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
KEF	Carbonate bank and terrace system of Van Diemen Rise	83	66	43	0.04	0.04	0.04
	Pinnacles of the Bonaparte Basin	6	-	-	18.3	-	-
	Carbonate bank and terrace system of Sahul Shelf	4	-	-	22.5	-	-
Fishery	Timor Reef Fishery (NT Managed)	1	-	-	23.4	-	-

Winter conditions (April to August)

Receptors		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Echo Shoals	8	-	-	17.9	-	-
	Big Bank Shoals	5	-	-	19.8	-	-
	Karmt Shoal	4	-	-	21.3	-	-
	Calder Shoal	2	-	-	7.5	-	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	5	-	-	22.4	-	-
	Dillon Shoal	3	-	-	28.1	-	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	1	-	-	34.8	-	-
	The Boxers	22	-	-	7.5	-	-

	Mataram Shoal	-	-	-	-	-	-
	Renard Shoals	-	-	-	-	-	-
	Giles Shoal	-	-	-	-	-	-
	Christine Shoal	-	-	-	-	-	-
	Margaret Shoal	-	-	-	-	-	-
	Wells Shoal	-	-	-	-	-	-
	Beagle Shoals	-	-	-	-	-	-
	Taiyun Shoal	-	-	-	-	-	-
	Hunt Patch	-	-	-	-	-	-
	Abbott Shoal	-	-	-	-	-	-
	Beatrice Reef	-	-	-	-	-	-
	Newby Shoal	21	-	-	3.3	-	-
	Barbara Shoal	-	-	-	-	-	-
	Afghan Shoal	1	-	-	0.8	-	-
	Bill Shoal	-	-	-	-	-	-
	Parsons Bank	-	-	-	-	-	-
	Taylor Patches	-	-	-	-	-	-
	Shepparton Shoal	22	4	-	1.3	1.5	-
	Tregenna Reef	-	-	-	-	-	-
	Harris Reef	-	-	-	-	-	-
	Moresby Shoals	-	-	-	-	-	-
	Knight Reef	-	-	-	-	-	-
	Hancox Shoal	-	-	-	-	-	-
	Oliver Reef	-	-	-	-	-	-
	Elizabeth Reef	-	-	-	-	-	-
	Draytons Reef	-	-	-	-	-	-
	Lowry Shoal	-	-	-	-	-	-
	Skottowe Shoal	-	-	-	-	-	-
	Flat Top Bank	10	-	-	3.4	-	-
	Marsh Shoal	-	-	-	-	-	-
	Lyne Reef	-	-	-	-	-	-

	Foelsche Bank	-	-	-	-	-	-
	Fish Reef	-	-	-	-	-	-
	Middle Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	35.3	-	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	2	-	-	1.7	-	-
	West Arnhem Land	-	-	-	-	-	-
	North West Vernon Island	-	-	-	-	-	-
	Kakadu Coast	-	-	-	-	-	-
	East Vernon Island	-	-	-	-	-	-
	Kakadu National Park	-	-	-	-	-	-
	South West Vernon Island	-	-	-	-	-	-
	Darwin Coast	-	-	-	-	-	-
	Joseph Bonaparte Gulf - Northern Territory	-	-	-	-	-	-
	Roche Islands and Reefs	-	-	-	-	-	-
	Peron Islands	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	72	11	1	0.7	0.7	0.8
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
KEF	Carbonate bank and terrace system of Van Diemen Rise	90	70	52	0.04	0.04	0.04
	Pinnacles of the Bonaparte Basin	16	-	-	10.2	-	-
	Carbonate bank and terrace system of Sahul Shelf	8	-	-	11.4	-	-
Fishery	Timor Reef Fishery (NT Managed)	19	-	-	6.5	-	-

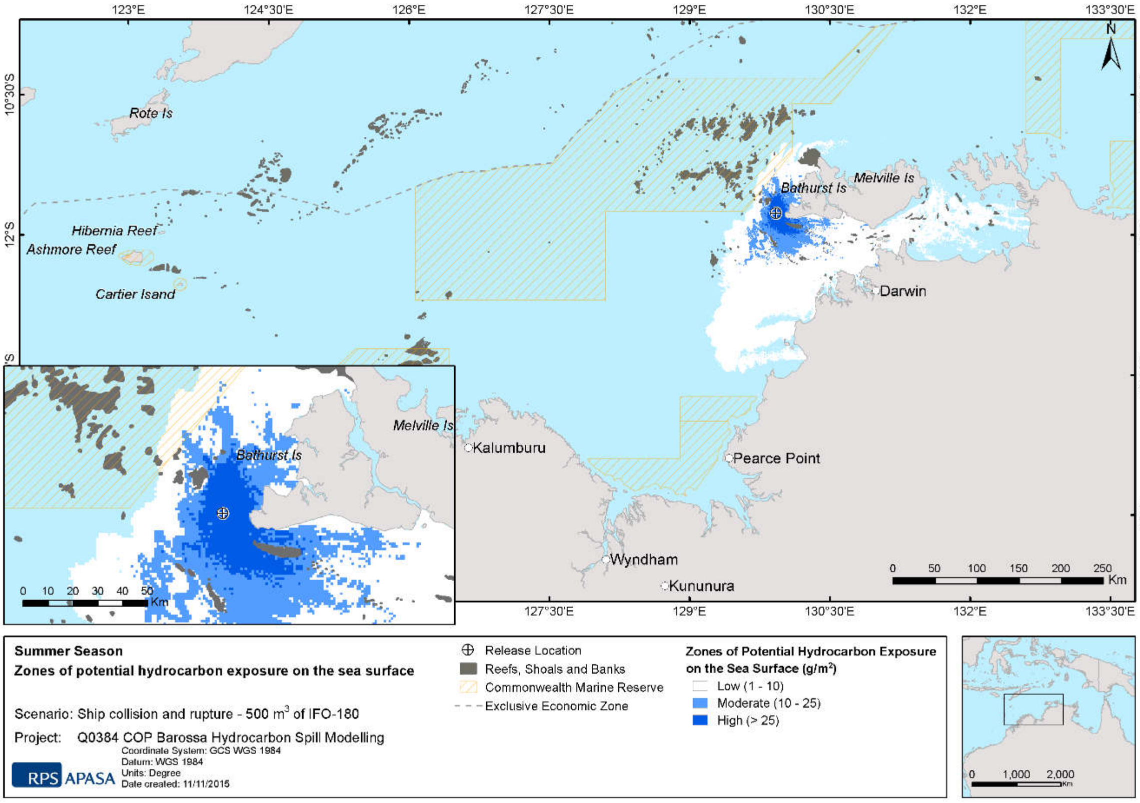


Figure 101 Potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions ($500\ m^3$ IFO-180)

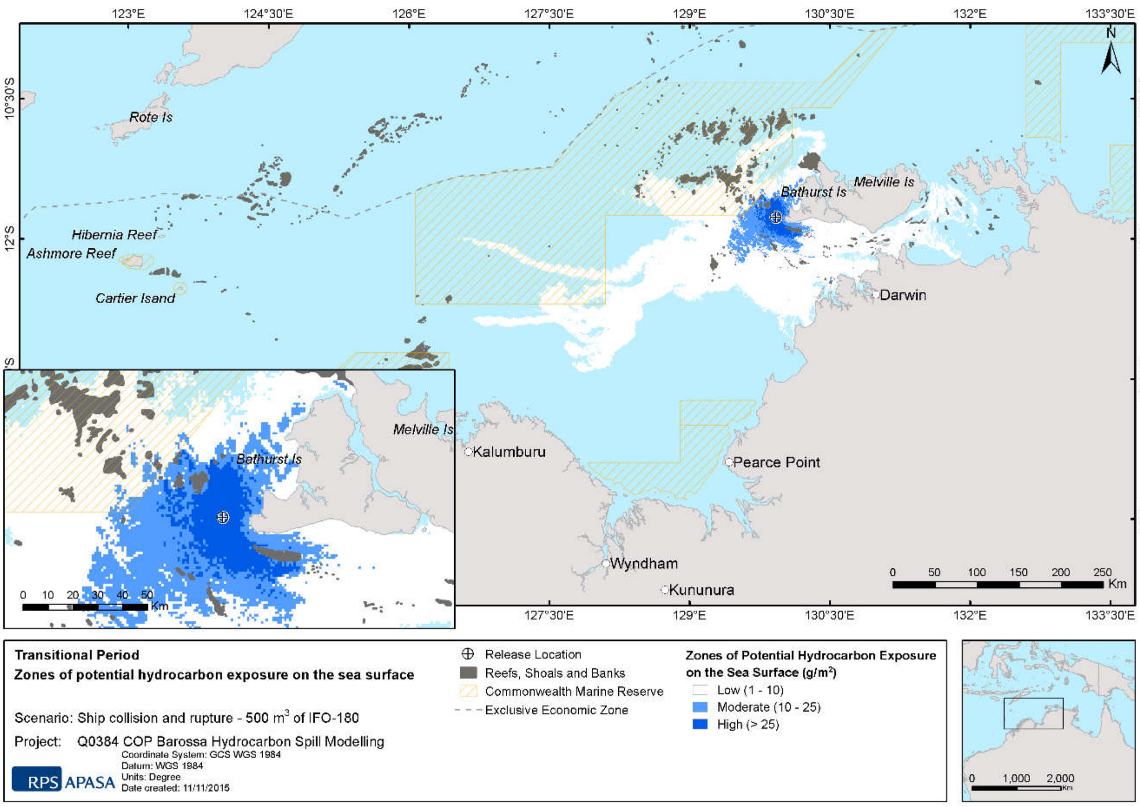


Figure 102 Potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions ($500\ m^3$ IFO-180)

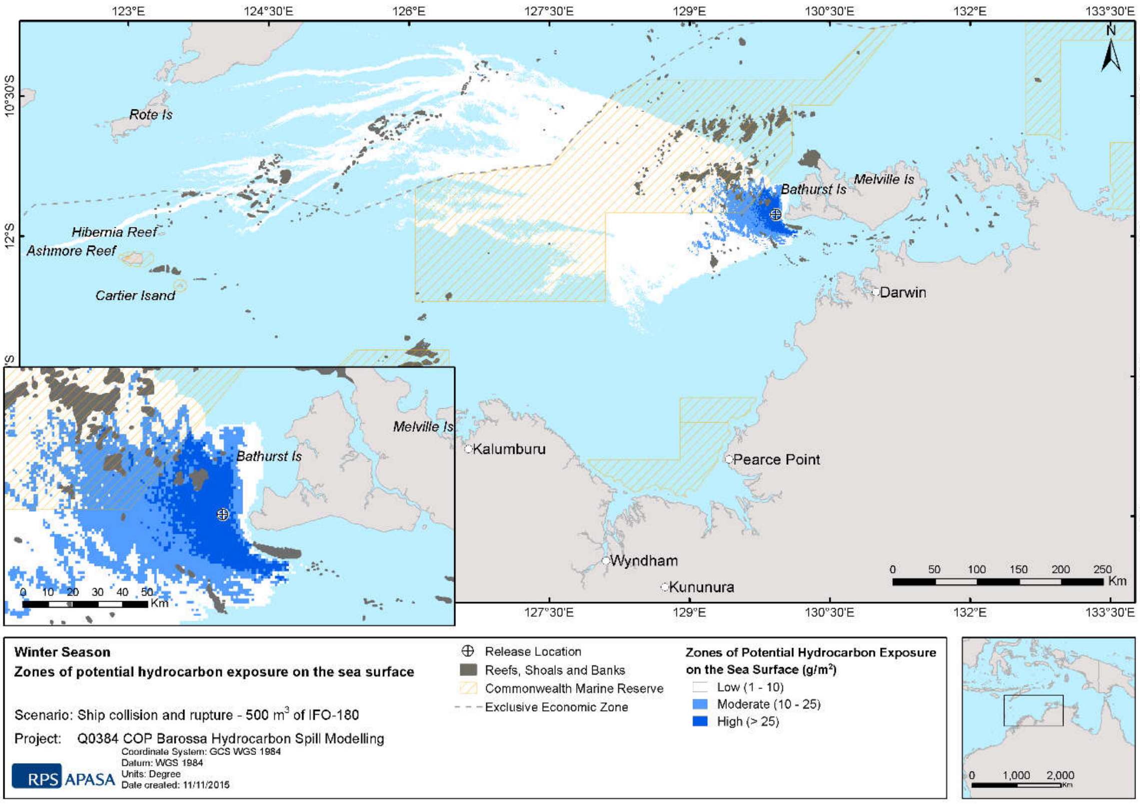


Figure 103 Potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (500 m^3 IFO-180)

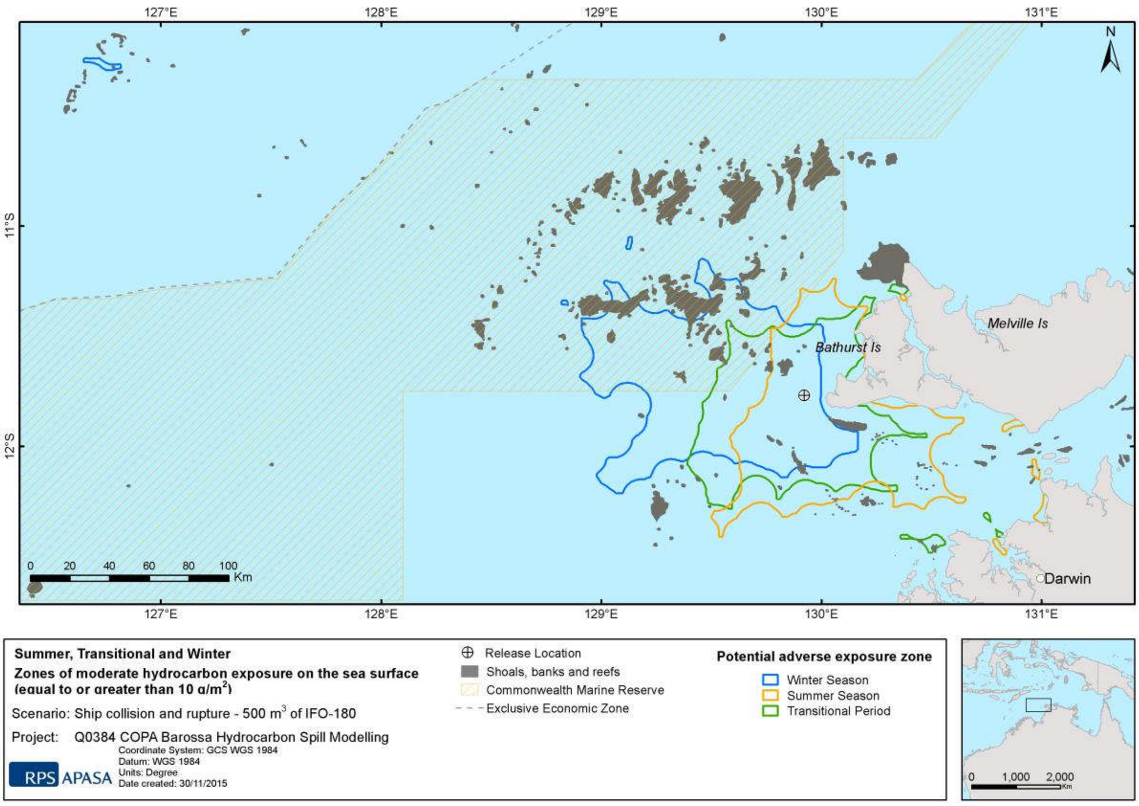


Figure 104 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a pipelay vessel collision releasing IFO-180 (500 m^3)

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